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THE CHEMISTRY OF THE POTTERY INDUSTRY.*

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The discovery of porcelain and the beginning of its manufacture in Europe was through the labor of a chemist, Friedrich Böttger, the story of whose quest for gold for the elector, Augustus II of Saxony, and the practical results of his experiments, is an oft-told tale.

Perhaps from the profession of its discoverer as a first reason, but certainly from the spirit that it should profit by all the assistance that science could render this beautiful art, the pet of the states and princes of the last century, the porcelain factories of Europe were among the first industries, except the pharmaceutical and metallurgical ones, to benefit by the constant assistance of chemists.

The national factory of France, at Sevres, was, from its beginning to the present time, almost constantly under the

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direction of men who ranked among her ablest chemists. And yet, the pottery industries at large, although they offer many problems whose solution lies purely within the province of the chemist, have given him practically no opportunity of adapting his researches to assist in lightening the difficulties that beset them. And it is only within very recent years that chemists themselves, who had rendered such signal service in the development of the most difficult and aristocratic of ceramic products, porcelain, felt tempted to extend their interest seriously and extensively to the more common but far more important products of the industry, from purely scientific interest. Yet, not until the field of ceramic labor was so extended by chemists themselves can their efforts even on behalf of porcelain, successful as they had been in their *results* in obtaining a beautiful product and rational manufacture, be said to have borne fruit from a chemical standpoint. For after all, if you consider the labor of even the most distinguished of the older chemists who devoted themselves to this work, Brogniart and Salvetat, they only assisted empiric experiment with general chemical reasoning and with analytical control of the various raw materials that were used.

Not until a later chemist, Dr. Herman Seger, who had directed his main energies to a study of the commoner clay wares, made his classic investigation on the nature of Japanese porcelains, was something like scientific light shed on the constitution of porcelain glazes in general, their relation to the composition of bodies upon which they can be melted without defect, and their chemical formulæ in relation to the general chemical formulæ of pottery glazes.

I take it that an important reason why chemists have had little opportunity to make themselves useful in the field of pottery manufacture, lay in the fact that the acquirements of one who would render service must lie in so many directions, and be coupled with so much practical experience relative to the physical and mechanical treatment of materials, that a knowledge of chemistry, without a practical apprenticeship in the craft, seemed a rather insignificant weapon with which to attack difficulties that are often like

the hydra, hundred-headed, and in which the chemical side is but a single factor. And this was particularly the case before something like a scientific groundwork had been laid of the constitution of pottery glazes.

Furthermore, experiences which have been made under the anxious strain of great commercial risks, as those of the potter very commonly are, in his having to submit to the uncertain element of fire, large quantities of ware upon which he has spent much labor, made in mixtures that are tentative, of materials uncertain in composition, and that to a single burning which, like the cast of a die, may win or lose, make a man timid, doubtful and secretive about the method of his results. And if the results of years of anxious experiment are reducible to the knowledge of a few particular materials and a few formulæ for mixing them, to the several components and colors of his ware, which he can record on a little slip of paper and carry in his vest-pocket, while he carries the standard for the measure of the fire, for perfecting them, in his eye, it is but natural that the maker of experiences which come down to such an absurd compass, and yet are so momentous to him, will have an exaggerated opinion of the value of receipts and of particular results instead of general methods. As he looks back upon the chaos of haphazard trials that have led him to his final results, he cannot believe that such experiments can be reduced to an orderly system. And he generally does not wish to know that such a system will accomplish, in a few hours of calculation and a few weeks of experiment, all that he required years to achieve. It would seem a mockery to his intelligence and a belittling of his most serious efforts. Fancy the wrath and contempt of Christopher Columbus, translated to this century, for a Cook's tourist who had made his tenth summer vacation trip to Europe!

Hence, I take it that the very risks and difficulties of the potter's craft gave its members so conservative, suspicious and secretive a temperament, that they were not willing to lay their experiences before a professional adviser, with the unreserved freedom that is essential to all theoretic service, whether it be a client disclosing his business transactions

to his attorney, a patient detailing his symptoms and habits to the physician, or a manufacturer laying his methods, his experiences and aims before the chemist or engineer. And so it is a curious chapter in human limitation, that while *chemists* solved the problem of making *porcelain*, though the skilled potters of Delft and of all Europe had failed, these, nevertheless, held aloof from seeking the service of the men who accomplished the most difficult feat in their own craft.

The pottery industries, instead of being among the first to find a field for the chemical engineer, as they logically should have been, are among the last. In Germany and France it is probably not twenty-five years since potters have thought of such a thing; in England and with us, it is not seriously considered yet.

After the passage of that celebrated English law, later copied in this country, which compelled manufactures of foreign make to be stamped with the name of the country of their production, England awoke to an astonished realization that the best of the wares she had approvingly fancied came from her celebrated Staffordshire district were "made in Germany"—by a country poorer in clays and fuel, whose labor and products she had always been content to look down upon as being what Professor Reulleaux had once stigmatized them with being, *billig und schlecht*—cheap and bad.

The reason of Germany's rapid and successful industrial development is well known, and it should be a source of hopeful satisfaction with us in America that while most of our industries have grown on English models, we are not so stereotyped in their adoption but that we are able to improve them by the aid of applied science and art from without the trammels of the particular craft, which England seems much less able to do. Our pottery industries are, perhaps, more distinctly English than any other. Our ware, our methods, the majority of our pottery workmen, are English.

The enterprise, diligent persistence and skill in empiric experiment which are characteristic of English industry, and have brought her pottery work to reputable perfection

and given some of the achievements high celebrity in ceramics (Wedgwood, Royal Worcester, Crown Derby, etc.), are qualities that have not left the men who brought the art to this country and have raised it to great commercial importance.

The time is now ripe for the application of scientific methods to its processes, as empiric ones can scarcely accomplish more than the results of our English prototypes, which we have already reached. Competition from our Continental rivals, with whom more scientific methods obtain, besets us. Artificial political barriers are foolhardy and a wrong, if they undermine the energy that prompts men to seize and learn all instruments for perfecting their craft.

The Franklin Institute, which has labored so long and so successfully in the cause of applying science to our industries, will, I am very sure, find it a grateful task to stimulate its aims in a field of great industrial importance that is, as yet, quite new.

Let me remind you what the material entering into the making of pottery is, and call your attention to the more common problems and difficulties that beset the potter. It will then be possible to give a brief survey of the resources that chemical methods and reasoning open for the solution of the technical questions that arise with him.

All ceramic products are, of course, fashioned from clay and are hardened to permanent form by baking or burning. But no raw material varies so widely in composition and physical properties as do the clays, and the products of no other material are put to uses as widely divergent, calling forth all the characteristics of its different kinds and those developed by the different treatment and degree and quality of burning to which they may be subjected.

Unlike every other mineral, it is never a question—is it rich enough or pure enough for the one or two objects of its utility? You may say, *a priori*, every clay has properties that make it of particular value for manufacturing some article of use. But the very wealth of its industrial application, and the variety of qualities which it can be made to exhibit and are the condition of its extensive and varied

use, have so overwhelmed men that they abandon hopelessly almost every attempt at an orderly and systematic investigation of the qualities which a particular clay deposit has, and pitch upon a use for it in the most haphazard way; or in selecting a clay for some particular use, go at the work in the blindest empiricism.

You can best appreciate this by investigating the commercial history of the clay industries. I think you will find that most factories have passed through one or two crises; that many are producing some other product than the one they were originally built for; that nearly all of them have paid so dearly for their technical experience; that their capitalization is higher than it should be, and that the cost of production is affected by the evil of having to perpetuate the consequences of a situation irrationally chosen and a factory system based upon the manipulation and burning of a material that had afterward to be abandoned without being able to abandon the machinery and kilns adopted for it. Thus much for the difficulties that the very abundance and variety of *the* pottery material par excellence raises; and if the difficulty of selecting the right kind, determining its proper mode of working and the kiln and temperature for burning it for a definite purpose, is already great, it will occur to you that these considerations are largely complicated, when, as in most cases, the clay is to be incrusted with other clays and glazes, and decorated, perhaps, with colors and enamels. Questions of shrinkage, of coefficient of expansion, chemical action and solution by the fusing glasses, come into play.

In the modern ornamental building brick and the vitrified ones, fast becoming our most important paving material, ordinary floor tile and drainage pipes, you have but the first considerations. But in all that you commonly think of, when one speaks of pottery, the thousand and one *containers*, of domestic, ornamental and industrial use, from the acid still and pump of the chemical factory to the soup tureen, the Dresden clock case or the Crown Derby vase, you have a clay form or body, covered with a glass or glaze, and often a decoration in color over or under the latter.

The following are some of the problems which the potter must solve: Architects require the ornamental terra-cottas and friezes upon buildings in great varieties of color. The clays which would produce them are, in the majority of cases, too expensive or often absolutely impractical for forming and burning the heavy pieces required. It, therefore, becomes necessary to make the body of the terra-cotta of a clay or mixture of clays that will have the necessary physical qualities, and prepare a series of encrusting clay mixtures that will adhere to it without defect, and produce, under the fire at which it must be burned, all the required tints.

All clays shrink considerably, both in drying and burning, and the shrinkage of clays differs materially not only in the aggregate, but in the different stages of drying and burning. If, therefore, the movements of the encrusting clay are not absolutely in unison with those of the body upon which they are placed, the former will shell off entirely or in parts. As the error does not always show itself at once, and as after the fire it is irremediable, and with it the entire product is lost, the problem is difficult in its subtlety and serious in its miscarriage.

The glaze covering on pottery is very difficult to obtain empirically. It must be a perfect glass in transparence and brilliance. But a *glass*, no matter how beautiful, cannot be melted upon pottery without devitrifying and entirely losing its characteristic qualities. The potter has, therefore, built up his glaze by himself without assistance from the glass-maker, and believes a *glaze* radically different from a *glass*.

But even with transparence and brilliance attained, the problems attaching to the making of the glaze are but begun.

In order to fulfil its principal mission of yielding an impervious coating to the clay body of the ware, which, even in the case of translucent and vitrified porcelain, is not absolutely impervious to the penetration of liquids, it must not crackle through use. In other words, it must undergo the same movements of expansion and contraction as the body upon which it is fused. These movements of a piece of

pottery under the fluctuations of temperature are very slight, it is true, but they are very positive, and transcend the limits of elasticity of both the glaze and the clay body, unless these are very closely adapted to each other in their coefficients of expansion, because of the intimacy with which they are attached to each other.

If the coefficient of expansion of the glaze exceeds that of the body and its movement goes beyond the elastic limit of the latter, the glaze will push off at the edges of the pieces of ware, tearing the clay off with it. And in case the disagreement is great, it will pull off the handles and spouts of the piece, or even shiver the whole to a mass of splinters.

Where the coefficient of expansion of the body is the greater, exceeding in its movement the elastic limit of the glaze, this cracks, and the fineness of mesh of the intersecting lines of fracture is directly in proportion to the degree in which the two are at fault.

This difficulty never occurs with glass itself, for it is due to the interdependence of the two bodies constituting the pottery piece.

It will, therefore, be clear to you that the composition of the clay upon which the glaze is to be used must itself be experimented with and modified to meet what cannot be accomplished by the glaze alone.

When these problems have been solved and a glaze and body perfectly co-ordinated, the decoration of the ware, by printing or painting with ceramic colors, may prove the glaze entirely unsuited to such treatment, and the labor of perfecting it and adapting it and the body to each other entirely in vain.

You will remember that after a piece of ware is fashioned it is commonly fixed to permanence by burning, before the glaze is applied. This first fire, which hardens the clay, is known as the "biscuit fire," and upon the "biscuit" or baked but unglazed ware, decorations which are desired of absolute durability, as in the case of dishes, or of particular brilliance, as in the finer faiences, are applied by printing and hand-painting in ceramic colors. Then the glaze,

ground to creamy consistence in water, is washed over the whole piece, and in a final glost fire it is melted to a transparent varnish, covering and absolutely protecting the decorations between it and the body.

The colors that are used must, in order to resist the high temperature requisite, consist of metallic salts and oxides, and these are all more or less soluble in melting glass fluxes. These colors must, therefore, be mixed so as to resist solution in the glaze that is to be fused over them as much as possible, and this must be of a character that its solvent action in fusing is small, for in this property glass fluxes vary widely. A glaze, perfect in every other respect, which eats off in melting these "underglaze" colors, as they are called, would be utterly useless for ware decorated in this manner.

Again, where glazed wares are to be gilded or decorated in easily fusible enamels and vitrifiable colors upon the glaze, decorations even more extensively practised, the glaze must stand repeated fires, at a temperature lower than its melting point, in which these are fused and fixed without suffering devitrification.

The composition of glass fluxes profoundly affects the tints produced in them by chromogenic oxides, and pottery decorated with colored glazes must be adapted to bearing a variety of these, though all must conform to the fundamental requirements of a uniform coefficient of expansion and being perfect glasses.

The first service that the chemist must render to supply data for the solution of these common problems and difficulties that beset the potter, and which I have enumerated, consists in classifying, or at least describing with positive factors, physical as well as chemical, the host of clays that geological, mining and engineering work are constantly disclosing and that the public is anxious to put to industrial use.

It is to be regretted, but it is, nevertheless, the case, that almost all the labor which chemists have spent upon countless clay analyses for geological surveys, whether at public or private expense, has been practically thrown away, for

the reason that none of them go far enough, and are accompanied with the necessary physical tests and descriptions to classify them, and give the practical worker a mental picture of what they will do under his kiln-heats and under his glaze.

In the first place, an elementary analysis of a clay, which is practically the only kind made, tells the potter little or nothing. Suppose you had a vinegar or a sugar syrup which you wanted analyzed, and the chemist to whom you took it should make a combustion of each and inform you how much carbon and oxygen and nitrogen and hydrogen they contained, what would you do? You would laugh at him.

You want to know how much acid the vinegar contains, and if some of the acid be malic acid, so that you can tell whether it was made from apple cider or not. You want to know, in the case of the syrup, how much saccharine matter it contains, and how much of it is cane sugar and how much glucose. Now all of these substances contain the same elements, carbon, hydrogen and oxygen, but they are grouped into compounds of very different properties, and the proportions of *these* are what you are anxious to know, because these and their amounts determine the value of the vinegar or the syrup.

Now let me explain the business of a chemist to you. He works largely by analysis; that is, by picking things apart, so that you will understand the character of a compound from its components. But there are two kinds of compounds, those which are mixtures and those which are homogeneous chemical bodies. The vinegar I spoke of is an example of the former, the acetic and malic acids it contains are examples of the latter. To pick apart the *mixture vinegar* so you will understand it, you separate the chemical compounds that compose it; to analyze the acetic acid, which is a homogeneous chemical compound, so that it may be understood, it must be resolved into its elements, carbon, hydrogen and oxygen, $CH_3.COOH$. If the chemist resolves the mixture at once into its elements, he goes too far and tells you practically nothing.

It would be like the anatomist who wished to show you

the structure of a chicken, and who, instead of removing the feathers to disclose the naked body, and the skin to display the muscles, and finally removed these to show the viscera and the osseous structure, put his bird into the meat chopper and reduced it to a pulp! His dissection would be so thorough that you could make neither head nor tail of it. Now this is just what chemists, out of touch with the pottery craft, have been doing. Instead of resolving unknown clays for the potter into the skeleton, the plastic muscle and the binding skin, they have put them into the analytical meat chopper and turned out elementary pulp!

Look at any geological or mineralogical book for the composition of a clay, and you will find some such answer as this:

	Per Cent.
Silica	50·02
Alumina	35·18
Oxide of iron	0·36
Lime	0·12
Magnesia	0·07
Alkalies	3·39
Combined water	10·57

And what does all this maze of elements mean? That this natural clay consists of

84 per cent. of true clay substance—*the plastic element*—the muscle.

9 per cent. of fusible mineral, feldspar—*the binding tissue*—which melts on baking and bonds the particles together.

7 per cent. of quartz or flint—*the skeleton.*

Now, you have the unknown clay resolved into its proportions of the three simple components of its structure, and the potter can tell you at a glance that *that* clay will not make a pottery body by itself. The skeleton is far too weak and the binding tissue insufficient; but he can now readily see how much flint and feldspar he must mix with his clay to answer for making his pottery body, and so he is saved much anxious work and tedious experiment by this solution of the chemist. But why has not the chemist answered thus simply and directly long ago? The simple analysis is hard to make, the simple answer the most difficult to find.

The glaze is a far more perplexing material to the potter

than the body, and I have enumerated a few of the difficulties that are encountered with it. It is made of a variety of materials that are difficult to survey, and, though the potter mixes these himself, from the fact that they lose their identity in fusion, it is difficult for him to foresee what the increase or diminution of one or the other will effect in the glaze. These are the constituents of common glazes: potash, soda ash, white lead, zinc oxide, borax, boracic acid, feldspar, Cornish stone, chalk, clay, quartz or flint. A porcelain glaze usually consists only of feldspar, chalk, clay and flint. Complex and different as these bodies are, you have, when they are melted together into a glaze, a homogeneous chemical compound.

In order that this may be surveyed and changed positively and at will to meet the different needs which I have indicated to you, the chemist must render the same service in reasoning about the glaze as he has about the clay and pottery body, namely, reduce it to the few simple elements of its actual structure. But, as the melted glaze is a homogeneous chemical body, like the acetic acid in the vinegar, it will be necessary to go into the chemical elements. Let us examine the very different materials I have enumerated for you as composing glazes—what do they consist of chemically, in all that would remain of them in melting?

The oxides of metals, as in the potash, soda ash, white lead, oxide of zinc, chalk—these the chemist calls "bases." Now, the quartz and the boracic acid are both acids and the borax, feldspar and Cornwall stone contain both bases, that is, oxides of metals and one or the other acid, and, finally, the clay, besides containing an acid—silica—contains the oxide of a metal—alumina—which does not exactly behave like the others, namely, as a base, but seems to occupy an intermediary position between a base and an acid. It is again a connecting link between these two, so the complicated glazes also consist of only three units, though these are composed of chemical *elements*,* as the body or the clay consists of three, though these are chemical *compounds*.

* It goes without saying that this term is not used in its strict chemical sense.

The scientific chemist will take some exception to these trilogies, but they are none the less useful for a practical comprehension of the facts.

Now, let me divide two glazes for you, and show you the application of such a chemical division:

	A	*B*
Borax	24	48
Chalk	25	12½
White lead	33	65
Feldspar	23	
China clay	23	26
Boracic acid	15½	
Quartz	57	63

Here are two glaze receipts. I question whether any potter would venture an opinion if either would give a perfect glass or not on melting, and if so, what the properties of each would be. It is practically impossible to do so, on account of the number and the mixed character of the constituents. But upon resolving them into their chemical divisions and elements, they are easily compared, and the phenomena of their behavior explained even by the potter untrained in chemistry. If he have the glaze mixtures which he uses in his work, and the experimental mixtures which he prepares, constantly reduced for him by a chemist into the fundamental chemical groups that compose them, the empiric receipts which can never be surveyed are resolved into intelligible factors, and a little practice in studying these, in conjunction with the phenomena that the glazes exhibit after coming from the fire, will soon enable him to experiment with a certainty in the direction that his aims dictate, which, without this help, is at the mercy of the blindest chance.

In order to make this reduction of empiric glaze mixtures into simple chemical formulæ, I prefer to do so by making use of the old "combining weights," which unite the combination of the elements by their atomic weights and by valence into one expression, reducing the sum of the "combining weights" of the bases to unity, or, perhaps better, to 10, avoiding fractions and chemical symbols as much as possible, so as not to confuse the practical potter.

The receipts given reduce to the following chemical formulæ:

A

2·5 Potash and soda. 5·0 Lime. 2·5 Lead oxide.	3· Alumina.	30· Silica (flint). 5· Boracic acid.
10·0 Bases.	3· Intermediary elements.	35· Acids.

B

2·5 Potash and soda. 2·5 Lime. 5·0 Lead oxide.	2· Alumina.	25· Silica (flint). 5· Boracic acid.
10·0 Bases.	2· Intermediary elements.	30· Acids.

The potter will find that mixtures varying widely from these in the proportions of their principal groups will not produce glazes under the conditions of the pottery glost fire, and he can spare himself the trouble of trying them.

A glaze that is high in silica is less likely to craze, but more in danger of shivering, so that *A* may shatter a body made of a siliceous clay mixture, upon which *B* stands perfectly. But the latter may craze upon a biscuit proportioned to carry *A*.

When the bases are rich in heavy metals, particularly in lead, and the acids in boracic acid, the resulting glaze has a high refracting index; glaze *B* is, therefore, more brilliant than glaze *A*. But lead glasses have a more yellowish cast than lime glasses, so that *A* is the whiter of the two.

The same factors that increase the brilliance of a glaze, a larger proportion of heavy metal oxides in the bases and boracic acid in the acids, lower the fusing point.

A proportionate increase of boracic acid and lowering of alumina increases the solvent action of the glass for chromogenic oxides. *A* attacks underglaze colors less than *B*, but the latter is the better basis for ornamental colored glazes.

The many phenomena exhibited by pottery glazes can be followed and understood by comparison with their chemical formulæ, but the examples already cited will suffice to show the assistance that a chemical division of their constituents can render in judging them. The same is equally true of the ceramic colors, with which the potter has to deal.

Perhaps the most mysterious of the seats of the potter's trials lie in the fire. This is the proof to which all his ware must be put, and here is the cause of his most perplexing failures. But this element, too, has been resolved by the chemist into its simpler phases, and the measurement of the higher temperatures by simple and accurate means, and the analysis of the flame by simple apparatus that can be put into the hands of any fireman, are accomplished facts, concerning which the potter can get full instruction from the chemist. It would, perhaps, lead us too far to discuss the chemical effects of the quality of the fire upon pottery colors, but I can illustrate its far-reaching results by two pieces of ware that I have here for the purpose, a piece of celadon and one of red Japanese porcelain.

The chemical formula of these two glazes is exactly the same; it is:

3· Potash. 7· Lime. Trace copper oxide.	5· Alumina.	40· Flint (or silica).
10· Bases.	5· Intermediary.	40· Acid.

The only difference in their treatment is that in the glaze fire this green piece was in a flame containing a little more air; it was in what chemists call an oxidizing fire, this red piece was in a reducing fire.

The difference in quality of flame was very subtle, but the result was radical and momentous. Perhaps the money value that the connoisseur would put upon them will tell this better—the red piece is of the order of the celebrated Japanese and Chinese red porcelains, known according to their tints as "ox blood," or "chicken blood," "*sang de boeuf*," or "*sang de poullet*." If the flame had been so perfect that the entire piece had been red, without the white portions, it would be worth several thousand dollars; as it is, it is only worth as many hundred, while the green piece is but worth as many hundred cents.

It is the business of science to disclose practical facts that lie a little under the surface and removed from the observation of ordinary men. It is necessary often to coin new names for these facts, and these sound very perplexing

while they are unfamiliar. But the facts of science and its terminology rapidly become common property of the masses, when there is use for them. You hear street-car motormen and telephone linemen talk of watts, and ohms, and ampères, and fields, and commutators, words only used by a professor of physics ten years ago.

Samuel Pepys tells us that in his time the multiplication table was a notable scientific discovery, and fellows at Cambridge University and men of scientific attainments studied it. We may smile at the simplicity of our ancestors, but it is likely that posterity will smile at us, for the chemistry of many of our common avocations is at bottom as simple and as necessary as the multiplication table in the market and the counting-house.

The multiplication table not only tells us what we can do, but what we cannot do—that we can get ten dimes, but that we cannot get five quarters, for a dollar.

So also, the greatest value of science applied to an industry consists in giving a survey of the attainable ground and the means of knowing what is beyond the possibility of achievement.

The empiric experimenter is an optimist, and believes that he can accomplish much which is simply unattainable. He, therefore, loses much valuable time in futile effort. He is like a fly that butts its head against a pane of glass, never realizing that transparent media may be impassable.

If, therefore, I have led any potter here this evening to hope that with chemical aid he may attain some object he has striven for in vain, in his body, his glaze, or his fire, I must warn him also that the answer he *may* get is that he has been on a fool's errand in his quest. I have tried to show you that in this age of industrial science we have an important craft, that in progressive England and America is still plodding along without scientific aid, although chemistry picked up the most difficult of its branches a century and more ago and brought it to perfection, when the cleverest potters of Europe could not do what it accomplished, namely, the making of porcelain.

I have tried to show you why the very difficulties of pot-

ting deterred the potter from calling the chemist to his aid, even after this demonstration of his abilities, but that the chemist was also in large measure responsible for this estrangement, in that he piled up analyses upon analyses for the clay-worker's benefit, but without a knowledge of his needs and, therefore, in forms in which he could not use them.

This period is passed. The chemist has penetrated the mysteries of this black art also, and, as I have tried briefly to sketch, can lay bare the practical conditions that underlie the problems of the potter and aid him greatly in his work.

SANITARY PROBLEMS CONNECTED WITH MUNICIPAL WATER SUPPLY.*

By Prof. W. P. Mason,
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This subject is in some danger of being over-written to-day; but we have about us material evidences that it is not over-studied, especially by those boards of public officials whose responsibilities are often much greater than their knowledge of sanitary principles.

Everybody seems to be talking or writing about water, but the public is very far from being well posted upon the subject, and one encounters all sorts of odd views, which are remarkable not only for their character, but also for the tenacity with which they are held.

Ocular evidence of purity is quite sufficient for most people. The bright and limpid water from a well which drains a graveyard is counted a blessing by those who would shudder at the thought of a cholera ship touching at one of our most distant ports. Nor is faith in the self-purifying power of running streams any less pronounced. The writer had the following curious criticism made of his report condemning the use of a sewage-laden river water:

"We would hint to Prof. Mason that every impurity

* A lecture delivered before the Franklin Institute, March 19, 1897.

which enters the river is either heavier or lighter than water. If it be heavier, it sinks quietly to the bottom; if it be lighter, it will remain on the surface a few hours, when it will be blown ashore by the wind.

"Water taken midway between the surface and bottom of the river will always be found as pure as the best spring water."

So long as such notions find expression in the daily press, so long, we may be sure, are the people ignorant and misinformed upon questions very nearly touching their safety, and so long there is direct need of suitable sanitary education.

It cannot be said, strictly speaking, that the adequate protection of a domestic well is a topic properly included within the limits set for us to-night; but, after all, it is upon the good sanitary conditions of the country-side that the purity of numbers of our brooks depends; and these small streams, even if not sources of town supply themselves, are tributary to the larger ones, whence the cities so often draw their water. Let it not be thought, however, that the writer would seek to protect every river in the country from all organic pollution.

Highly desirable as it would be to keep the waters of our great rivers in their natural condition of potable purity, the enormous expense of attaining to even an approximation to that state of things would be prohibitory, aside from a consideration of the great injustice to established institutions which would be caused.

Very large centers of population are already in existence, which turn their sewage directly into the river upon the banks of which they stand, and the up-stream city might well complain should it be forced, at great expense, to establish sewage-disposal plants, when the town below, for much less money, could secure a superior water from some purer inland source.

To the writer's way of thinking, a land should be looked upon as watered by its smaller lakes, its springs, and its brooks and streams, and sewered by its great, especially its navigable, rivers. Its water-sources should be protected by

law with exceeding care, and no river or stream should be added to its list of drains except after proper consideration by the State Board of Health, followed by legislative permission.

You probably recall that notable instance of the typhoid fever outbreak at Plymouth, Pa., the attending circumstances showing, as they did, the direct relation between epidemic disease and a polluted water-shed.

It will be remembered that this most serious and fatal outburst of fever was traced to a single typhoid patient, whose dejecta were thrown out upon the snow of a frozen hillside, at the base of which ran a small stream, whence the town water supply was ultimately drawn. Let it be noted that a period of weeks elapsed, during which the dejecta in question were frozen solid before the March thaws permitted the melting snows to wash them into the stream below. This failure of frost to protect against infection is but in accord with what we already know concerning the action of low temperature upon germ life. Prudden showed long ago that the typhoid bacillus can survive three months continuous freezing; while Dewar more recently found germ life to withstand exposure to the temperature of liquid oxygen (— 295° F.).

Cases such as that of Plymouth impress upon us the necessity of caring for our water-sheds and the ultimate ramifications of the tributaries to our sources of supply.

Beyond a peradventure, it is dangerous to allow human refuse material to be so disposed of as to permit of its being washed over rocky or frozen ground into neighboring brooks; and no town authority, worthy of its trust, would permit such a condition of things to obtain. But it is necessary for us to go a step farther in our precautionary measures.

Most of my hearers are probably familiar with the excellent experiments carried on at Lawrence by the Massachusetts State Board of Health, which go to show that by carefully conducted intermittent filtration through beds of sand or gravel stones, city sewage may be converted into what may practically be called potable water. Let these two very important points be always kept in mind, however:

first, the filtration must be intermittent; for if it be continuous, the atmospheric oxygen necessary to the activity of the purifying organisms of nitrification becomes excluded and purification ceases. Secondly, the dose of applied sewage must not be larger than that quantity which experiment has shown to be capable of disposal by the filter. In view of all this, what now are the conditions that we find obtaining upon many a farm and within the limits of many a town?

Human dejecta are disposed of by deposit in a vault or cesspool and the purifying power of the earth is depended upon to prevent pollution of the family well or of the adjacent stream.

Those who are acquainted with the unwise location and the filthy condition of many of the country privies must appreciate that the distance from them to the family well is often short, and that the intervening soil is required to dispose of an amount of filth greatly in excess of its powers, and that, too, by a process which must be essentially a continuous, rather than an intermittent, form of filtration.

That organic pollution of the soil is not disposed of within short distances has been definitely proven by Vaughan, who says: "I dug down a foot behind a privy vault and took up some soil 3 feet below the surface to determine the amount of organic matter in it; then I went off 6 feet and did the same thing, then 12, then 18, then 24, then 30; and, without going into detail, suffice it to say that the contamination of the soil from that single privy, built upon nearly level ground, could be detected 50 feet from the vault plainly."

The claim of typhoid fever to be a country rather than a city disease, is, for the State of New York, approximately represented by the ratio of the figures 33 to 24. The average annual typhoid death rates for thirteen Massachusetts cities stand:

Before introduction of public water supply	7·94 per 10,000
After such introduction	3·83 " "

For the whole State of Connecticut the per cent. of typhoid deaths to total deaths has fallen from about 5·8 in 1870 to 1·84 in 1893.

Such figures show the advantage of more or less carefully selected public waters over the general run of those derived from domestic wells.

We are all familiar with the ordinary country well, and we can, unfortunately, testify to the opportunity at times existing for pollution entering at its open top, but it is hard, indeed, to believe, as some would have us do, that all well infection is to be accounted for in that way.

Dr. Barwise's experience during the typhoid epidemic at South Wingfield,* in 1892, is interesting in this connection. He found that typhoid excreta, which had been carefully buried, so polluted the drainage that the infection was carried to a large number of people lower down the hill, a fact that certainly shows inefficiency of soil filtration in that instance.

So convinced has the writer become of the danger to health, arising from the unsanitary methods practised for the disposal of excreta in the country, that he has more than once attempted (unsuccessfully) to have the law direct that all such material should be subject to frequent removal, and that if buried, the place of such burial should be very often changed, so as to secure all the advantages arising from an intermittent form of sewage filtration.

The general trend of our information goes to establish the fact that proper care of the water-shed is as necessary as it is unusual, and I firmly believe that such care should be carried even to the extent of protecting the ground-water for a reasonable distance before it enters the draining brooks of the district.

After a suitable and well-protected gathering-ground has been secured, and after the water has been started on its way to the consumer, other opportunities for material pollution not infrequently arise. The larger cities of our country construct aqueducts or pipe lines which carry the water from the point of collection to that of distribution, under circumstances which preclude the introduction of sewage material, but such an arrangement is by no means univer-

*"Disinfection and Disinfectants," Rideal, p. 150.

sal. Open channel-ways as means of conveying water to a town are quite commonly seen, and care is not always taken that pollution shall not reach the water during its flow therein. To go back a few years, we find a very noteworthy case of contamination under just such circumstances recorded in the history of the cholera epidemic at Messina, Sicily, in 1887.

The plague lasted from September 10th to October 25th, during which time there were some 5,000 cases and 2,200 deaths. Although for a time the number of daily cases was excessive, running as high as 400, the ordinary number was about 70. The population was stampeded, falling from 71,000 to about 25,000. The government felt that a very possible cause for the rapid spread of the scourge lay in a contaminated drinking water, and an inquiry, resulting in the development of the following facts, fully confirmed the suspicion: The water as it left the gathering-grounds in the mountains was of excellent quality, but it was conveyed to the city in a conduit entirely open. Those who are familiar with European customs will remember that the washing of soiled linen is there largely an out-of-door occupation, conducted in the nearest available water-course. For the benefit of the Messina washerwoman a portion of the public water was deflected, before reaching the walls, and turned into neighboring washing-pools of stone. A fair proportion of this deflected water, after having been used for laundry purposes, found its way back into the channel, and continued its course to the city. Further contamination occurred within the town itself, for the reason that the mains of the distributing system were of unglazed tile, badly joined, and were laid in the immediate vicinity of unglazed tile sewers, also very leaky. The sewers were at times found on top of, and parallel with, the water-mains.

Acting upon its conviction as to the cause of the great mortality, the government sent tank ships to the mainland, filled them with pure "Serino" water, supplied the people therewith, and the daily number of cholera cases immediately fell from seventy to five; or, to quote an expression of the time, "the plague ceased as if by magic." An entirely

new and efficient distributive system has since been introduced, the open conduit has been replaced by modern pipe and the city has escaped further visitation by cholera.

The influence of the washerwomen in spreading cholera in Messina reminds us that the great epidemic at Cuneo, Italy, in 1884, resulting in 3,344 cases, was traced to identically the same source. Infected linen had been washed in a brook communicating with the public water supply.

Perhaps one of the most common means of fouling these open waterways depends upon the claim of some riparian owner to exercise his right to "water his stock." Most varied notions seem to dwell in the minds of sundry interested parties with reference to what the legal limits of this "watering" may be.

However much the meaning of the expression may be tortured and twisted by the experts of the bar, the ordinarily sane and disinterested layman must surely hold that the giving of drink to animals is all that the spirit of the law ever contemplated, and that no license to pollute the stream with excrementitious matter and general barnyard drainage was ever intended. Within the very recent past the writer counted no less than twenty-six cows in a pasture through which ran the open water course connecting the storage and distributing reservoirs of a city. The animals had perfect freedom to wade in the stream to within a few hundred yards of the point where the water entered the city mains.

Such public sanitation is very faulty, even upon æsthetic grounds, and outside of any question concerning the production of disease through the ingestion of fæcal material from sources other than human.

Placing our attention upon typhoid fever for the moment, it will be remembered that two conceptions of its origin are entertained by opposing schools of bacteriologists. On the one hand it is held that the typhoid germ is always the offspring of a bacillus of its own kind; while, on the other side, there are those who believe, and it is a very conceivable belief, that the progenitor in question is often a saprophyte which takes on its pathogenic properties by culti-

vation through successive generations under favorable conditions.

Many illustrations are available, in the world of larger vegetables, of great changes in structure due to cultivation under an altered environment.

Roux and Rodet are perhaps the leaders among those who claim a saprophytic ancestry for the typhoid germ, but they are not without a strong following in this country, especially among the medical officers of our army, who "look with favor on the theory of a *de novo* evolution of the typhoid fever germ from saprophytes in the soil as the only method of accounting for the occurrence of cases during field service when the troops have been operating in unsettled parts of the country for weeks before the febrile attack became manifest."*

Whatever may be the final decision of the specialists upon this knotty point, it is our manifest duty, as guardians of public health, to adopt for the present the saprophyte theory as our working formula and to protect our water supplies from infiltration of animal waste material, from whatever source, remembering that the presence of filth and the production of disease are very closely related.

As directly connected with what we have touched upon, namely the conveying of water in open channels, comes the question of the self-purification of water under such circumstances, and we are at once confronted with the strong views held thereon by the public at large. Despite the very great amount of published testimony tending to show the restricted limits within which self-purification in running streams is possible, the people have an abiding faith in the thorough efficiency of the same, and their belief in the great benefits to be derived from a short distance of open flow appears to be beyond the power of science to weaken.

Agitation and aëration do certainly aid in preventing abundant growth of algæ, with their objectionable tastes and smells; and an undoubted improvement in quality of water results from the establishment of a fountain in, or

* Surgeon General's Report, 1896, p. 44.

otherwise blowing air into, a too quiet reservoir; but the expectations of those who hope to thus easily eliminate pollution of a serious character will not be realized.

So far as aëration is required to furnish oxygen, wherewith the nitrifying organism can do its work, it has long since been pointed out that the bacterium does not suffer any loss of its efficiency, even though the oxygen be greatly reduced in quantity below the normal supply. The presence of some oxygen is essential; but just as complete oxidation is obtained when 3 or 4 per cent. is furnished as when the full allowance is supplied.

Sedimentation plays a part in the general purification during open flow—but it is commonly a small one, particularly small in such streams as stand in especial favor with the public, because of the riffles and other interruptions in their courses.

The influence for good of the higher organic life must also be recorded, but even with this reinforcement the sum total of self-purification which occurs during the flow of a polluted stream is so insufficient as to permit of the carriage of infection for many a mile towards the sea. Instances substantiating this statement would but weary the hearers by their numbers and sameness.

To revert for a moment to a former paper of mine, read in this hall some years ago, the point was made, and I think sufficiently established, that the rate of self-purification of water varies directly as the amount of contamination; that is to say, the amount of pollution disappearing per mile of flow, stated as per cent. of the total pollution present, will be greater in a water heavily laden with sewage material than in one relatively much purer. Consequently, the rate of purification decreases as the stream flows on.

Some of the means for the self-purification of water, which we find so insufficient in running streams, do, however, arise into very respectable dimensions, indeed, when we consider the question of drawing our supply from a lake, particularly a large one. Sedimentation in such an instance becomes of prime importance, and as the element of time enters so largely into the consideration of these

cases, material changes for the better are often noticeable in lake waters: thus the tributary of a lake may be undesirable for domestic use, while its outlet may be entirely satisfactory. It is interesting to note in this connection, however, that sedimentary deposits of polluting materials should not be disturbed after settlement, for they may retain their objectionable properties long after they have separated from the water levels above them. The writer has had occasion to observe this in connection with sub-aqueous blasting; and Rafter quotes the coincidence of outbreaks of typhoid fever at both Zurich and Geneva, Switzerland, with dredging of the lake bottom and consequent stirring up of the deposited mud. In similar manner, any large and shallow lake which is subject to gales of wind, must necessarily be often stirred throughout its entire depth by violent wave action, with consequent deterioration of its waters.

Among the great lakes of North America, Lake Erie is an instance of such a condition of affairs, its depth being but 90 feet on the average, an insignificant showing when compared with its much deeper neighbors.

The relatively small lakes, of perhaps no greater depth, particularly those which are protected by neighboring mountains, furnish conditions very much more suitable for quiet sedimentation. Wave action is of course present in these lakes as well, but the depth to which it extends will rarely exceed about 20 feet, and when once the falling sediment passes below that plane there is no chance of its being raised again except through the agency of vertical currents established by variations in the water temperature.

Let us consider for a moment how such currents may be formed.

Fancy the upper water layers of a lake heated by the summer sun and consequently rendered specifically lighter than the colder bottom ones upon which they float; as the cooler autumn season approached, the surface water would gradually cool down until, towards the verge of winter, a temperature would be attained which would increase its

gravity to and beyond that of the lower layer upon which it floated.

When this point was reached, vertical circulation would be at once established, and the lake would "turn over."

With the advent of freezing weather, a second period of stratification would be inaugurated, which would continue until the surface thawed again in the spring. Vertical circulation would then progress until the warm sun of later April rendered the surface water so light as to permit of its floating upon the colder layers beneath, when summer stagnation would again begin.

All this is a matter of importance to the water consumer, because it becomes advisable to avoid, if possible, drawing the supply from the stagnant layer, if the same be resting upon a dirty bottom, for the reason that such water is of necessity heavily charged with products of organic decay. Let it not be supposed that water from such a layer is objectionable *per se;* clean water stored in clean reservoirs must form layers, of course, but the bottom portions may be used and enjoyed as freely as those nearer the surface.

When the periodical "turn-over" takes place, the water which has rested upon a dirty bottom starts upon its upward course, carrying with it and diffusing throughout the entire lake body, the accumulation of extractive materials it has gathered during its period of rest. As a result, much plant food is distributed through the upper water, where the presence of suitable light and air encourage the development of quantities of minute plants, whose growth and decay cause the unpleasant tastes and smells so often met with in our city supplies.*

Perhaps it might be of interest in this connection to refer to a suggestion recently published by one of our sanitary engineers, to the effect that the cleaning of storage ponds is all a mistake, and that it would be far better practice to leave the vegetable *débris* where nature placed it, and even

* The relation of this growth of "diatoms" and the annual "turn-over" is very beautifully illustrated by G. C. Whipple. *Technology Quarterly*, IX, 145.

add to the vegetation rather than to diminish it. It must be replied that comparative experiments upon reservoirs have shown that improved water unquestionably follows cleaning; and it must be, moreover, remembered that, while good water may be obtained from swamp sources where vigorous growth disposes of the products of decay, yet quite the reverse obtains under conditions which permit the products of decomposition to accumulate.

In connection with this let it be said that the bottom of a proposed reservoir should, so far as possible, be cleaned of all varieties of vegetable material, and it is even desirable to also remove a portion of the upper soil, as it commonly carries quantities of organic remains. Decomposition of recently killed vegetation takes place under water quite rapidly at first, but the process is shortly converted into one of exceeding slowness, particularly where the covering water is deep. So permanent, in fact, is timber which has been deeply submerged, that the oaken piles, which, in prehistoric times, supported the buildings of the Swiss "lake dwellers" are still firm and solid, although black in color. Alternate flooding and exposure to sun and air is quickly destructive of vegetable matter, and, as a result, a reservoir with very gently sloping sides furnishes conditions favorable to a contaminated water supply, particularly if it be liable at times to considerable reduction in depth of water. Even though the level of its contents be always maintained at high-water mark, sloping sides would permit thin layers of water to be overheated by the summer sun, thus encouraging abundant growth of aquatic plants, which subsequently decay, to the damage of the water.

It is especially undesirable to permit the bottom of a storage-reservoir to remain exposed for more than one season, for the reason that vegetation will develop in such quantity as to greatly damage the water when the bare slopes are again submerged.

Owing to experience already obtained in such matters, the Boston authorities propose to remove the soil from the site of the new Nashua reservoir (about 7 square miles of area), at a cost of $2,909,000. "In order to deter-

mine the amount of soil to be removed, a number of test-pits were dug in representative localities to a depth of 3 feet, and from the sides of these pits samples of the soil were carefully collected at different depths. Analyses demonstrated that the amount of organic matter in the ground was generally so small below the layer of black loam that it would be necessary to remove only this layer." Some 800 holes were dug to determine the average depth of this layer, and it was concluded to remove 9 inches from the wooded portions, and 11½ inches from the cleared lands.*

No stripping of the soil from the bottom of the Vyrnwy reservoir, supplying Liverpool, was done, but the water is filtered before delivery for consumption. Filtration is so common in Europe that the same care in storage is not so necessary as it is in this country, where the practice is to pipe the raw water direct to the consumer.

As an instance, showing the necessity of thorough removal of the upper soil-layer from a proposed reservoir site if bad odors are to be avoided, the very recent experience with Reservoir M of the New York Croton water system is a case in point.

So obtrusively penetrant did the odor become that many folk, believing the water to be infected, closed up the wells from which they procure their drinking-water, and some were even forced to abandon the hamlet as a residence until the atmosphere regained its purity and pleasant odor.

The reservoir was built on condemned land, on which formerly were gardens, orchards and dwelling houses, and through which meandered a small stream known as the Titicus. The 1,000 acres of land covered by the reservoir were cleared of everything excepting the growth of grass, which was left in most cases intact, or at least was not ploughed.

For such as may not be familiar with the exceeding foul smell fresh green grass will give if steeped in water it might be interesting to try the experiment upon a small

* Massachusetts Board of Health, 1895.

scale by covering some with water in a bottle, and allowing it to stand a few days.

Depth of reservoirs is not so important as the presence of food-supply in the matter of the existence or absence of organisms. The Massachusetts Board of Health reports the case of Pilling's Pond, a very old storage-reservoir, 85 acres in surface, with an average depth of only 3 feet. No abnormal growths appeared in this reservoir, nor did the water become offensive, although its temperature at times reached 80° F. The explanation offered is that, owing to the age of the reservoir, the bottom mud no longer contains food-supply.*

Sulphuretted hydrogen frequently adds its disagreeable smell to the offensive odors occurring in new reservoirs, particularly shallow ones. The decomposition of vegetable material, killed by flooding, causes a reduction of the sulphates present to sulphides, and these sulphides are further acted upon by the acids, also formed by such decomposition, with liberation of the foul-smelling gas. The author found this gas on one occasion due to a somewhat unusual cause. The reservoir-dam had been built of blast-furnace cinder, and the water was in consequence, strongly impregnated from the sulphur compounds contained therein.

Waters from underground sources should be distributed for use as soon as possible after they have been brought to the surface; for they are commonly well supplied with plant-food in solution, and, under the influence of light and air, there is danger of abundant development of objectionable algæ if much time for open storage be allowed.

With surface-waters the case is quite the reverse, and long storage becomes a distinct advantage if the reservoir be clean.

Sedimentation of suspended impurities, and destruction of bacteria by simple lapse of time, are two sources of benefit arising from impounding of surface-water.

Bacteria often die but slowly, and although a large percentage of their number will disappear through storage, it

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* Massachusetts Board of Health, 1890, **1**, 749.

should not be forgotten that they are very small and very light, and consequently are very long in settling; so that it should not be expected that a reservoir could do the efficient work accomplished by a filter.

Percy Frankland found the following numbers of bacteria per cubic centimeter in Thames water at the intake of the Grand Junction Company, and in water from the large reservoir of the company, where the greater part of it had been stored for six months, and none for less than one month:

	Bacteria.
Intake	1,991
Reservoir	368

The value of sedimentation was shown at Philadelphia during the prevalence of typhoid fever in that city in 1891. "By much the highest mortality is in the Twenty-ninth and Thirty-second Wards. This is an elevated section of the city, newly improved and occupied for the most part by well-to-do people. The drainage is good and the laws of health are doubtless as well observed as in any other portion of the city. But these wards are too high to draw water from the subsiding reservoir, and they are accordingly furnished by direct pumpage from the river. This is the case also in the Twenty-eighth Ward adjoining, and the district so supplied extends southward including the Fifteenth Ward, another well-to-do part of the city, where typhoid is especially prevalent. These four wards, furnished by direct pumpage, have a population of 184,000, and report 317 cases of typhoid fever, or at the rate of 172 to 100,000 inhabitants."

The West Middlesex Company causes its water to pass through two storage-reservoirs before it is delivered upon the filter-beds. The influence of such passage is seen in the following counts of bacteria as made by Frankland:

	Per c.c.
Intake at Hampton	1,437
After passing first reservoir	318
" " second "	177

The influence of precipitating mud in hastening the fall

of bacteria was investigated by Krüger.* By the use of ½ gramme of fine sterilized potter's clay per liter of water he obtained the following counts of bacteria per cubic centimeter of water. The temperature was maintained at 55° F.

	Water with Clay.			Control Water Containing No Clay.		
	Top.	Middle.	Bottom.	Top.	Middle.	Bottom.
After standing 2 hours	575	887	33,495	5,340	6,110	5,480
" " 20 "	521	155	43,595	5,960	6,710	6,210
" " 50 "	6,933	6,190	66,350	7,230	3,987	6,924

This action was to have been expected, in view of the well-known tendency of falling solids to drag down other matters with them, even at times when such other bodies are in solution. Bacteria, being in suspension, are more readily influenced by the depositing silt.

Having once entered the city mains, there is yet possibility of local contamination reaching a water, as we have seen was the case at Messina, Sicily. The ancient town of Pisa, at a recent date, also presented a similar instance of contamination from leaky mains lying near broken sewers, although the thorough change that has been made in the distributive system of that city has remedied all that difficulty. In our own day and generation such accidents are not unknown; and it has chanced that on two occasions the writer has seen water pipes in direct contact with sewage, and, in one instance, the main of a large city street actually cut through the sewer.

Fears are allayed in such cases by the argument that the pressure of the water in the pipe would surely cause a flow outward, not inward, in the event of rupture; but when one calls to mind the familiar laboratory device known as the "Richards pump," which depends for its action upon the power of the rapidly moving water to suck air in at the open side tube, one feels that circumstances might so obtain as to permit of the "Richards pump" principle coming into play,

* *Zeit. f. Hygiene*, 7, 86.

and should such an accident happen, the results would be most unsatisfactory.

From whatever source the water may be derived, it is the common American practice to deliver it "raw" to the consumer, even when its appearance is distinctly unsightly. Such is not the European custom. Public sentiment abroad demands that surface waters should receive efficient purification before they are distributed for domestic use, and in Germany such purification is regulated by statutory law. As a result, filters are established or arrangements are contemplated for their erection to filter waters of a degree of natural purity equal to the best supplies America can show. We, on this side of the Atlantic, would consider the expenditure of money for the purpose of purifying such waters as we find at Zurich and Liverpool, quite unnecessary and superfluous. Europeans think differently, however, and their notions are best expressed by Voltaire's apothegm: *Le superflu—chose tres necessaire.* It is very amusing to note the care with which Americans, perhaps from Albany, Pittsburg or Chicago, scrutinize the water offered them in foreign capitals, when what they are in the habit of drinking at home would not be tolerated for an instant in the great cities of Europe.

The day is past when we could feel a sense of superiority over the crowded millions of the old world, because of the relative magnitude and consequent initial purity of the sources of our water supplies. Europe has, of late years, expended much labor and capital in substantial plants that make for sanitary betterments, while we have continued upon a conservative course, forgetful that our populations and industries have been growing, and that the river our fathers drank from with pleasure and safety has become charged with the refuse of up-stream communities, and converted into what may be properly styled the county sewer.

These improvements for the betterment of water, into which Europe has gone so largely and from which we so uniformly shrink, cost much money. Do they pay?

To abandon an existing water supply system or to purify the polluted water that it furnishes, always involves the

outlay of much money, and the city taxpayer has the right to inquire whether or not the benefit derived is a fair equivalent for the cash expended. Impure water affects the yearly death-rate, as a whole, much less than that section of it which deals with diseases recognized as "water-borne," prominent among which is typhoid fever. No better measure can be selected of the wholesomeness of a city supply than that furnished by a list of the annual cases of this serious disease.

Typhoid fever is doubtless, to a very large extent, a preventable disease, but the means of prevention, in the shape of great public works, are expensive, and again the question is asked, do these works pay? Can we afford to save the typhoid victims?

According to Rochard, the economic value of an individual "is what he has cost his family, the community, or the State for his living, development and education. It is the loan which the individual has made from the social capital in order to reach the age when he can restore it by his labor."

The statement of this value, in form of money, is a difficult matter, which has been variously settled by sundry investigators. Chadwick considers an English laborer equivalent to a permanent deposit of £200 (say $980). Farr gives £159 (say $780) as the average value of each human life in England. A French soldier is rated as worth 6,000 francs (say $1,200).

In view of the fact that typhoid fever selects by far the greatest number of its victims from among those in the very prime of life, to the relative exclusion of the very young and the very old, it will be reasonable to follow the figure fixed upon by E. F. Smith, and place the loss caused the community by a death from typhoid at $2,000. This will be noticed to be less than half the figure so frequently referred to in the courts of the State of New York for the value of a human life.

From the statistics issued by the health office, it appears that the annual average number of deaths from typhoid fever, which occurred in the city of Philadelphia during the five years 1890 to 1894, inclusive, was 523.

Rating the money value of each life at the figure given above, this death-rate would mean an annual pecuniary loss to the city of $1,046,000.

Funeral expenses are variously estimated at from $20 to $30. Should we accept the intermediate value of $25, this item would cause $13,075 to be added to the above sum, thus raising the total direct loss through death to $1,059,075.

But typhoid fever does not always kill. Its mortality rate is commonly quoted at about ten per cent. For the present purpose, should we assume nine recoveries for each death from the disease, and place 43 days as the period of convalescence (the average of 500 cases at the Pennsylvania Hospital), we should have a term of 202,401 days as representing the time lost, per year, by the 4,707 persons who have the fever and recover. Thus an annual loss of over 554 years has to be borne by the city's capital of productive labor.

This great amount of enforced idleness, when translated into money value, should very properly be added to the death loss above estimated.

Fixing the rate of wages at $1 per individual per day—a very low figure, considering that the bulk of typhoid patients are in the very prime of life—there is a loss of $43 of wages for each recovery, or a total yearly loss for the city from this item of $202,401. The cost of nursing and doctors' bills equal at least $25 per case, which is a very low estimate, thus adding the further amount of $117,675 to the gross sum.

Expressed in tabular form, this yearly tax imposed by typhoid fever upon the citizens of Philadelphia would stand:

523 deaths, at $2,000 each	$1,046,000
523 funerals, at $25.00 each	13,075
Wages of 4,707 convalescents during 43 days, at $1.00 per day	202,401
Nursing and doctors' bills for 5,230 cases, at $25.00 per case	130,750
Total annual tax levied by typhoid fever upon the city of Philadelphia	$1,392,226

Public works which could eliminate a reasonable fraction of this great tax would certainly pay for themselves in the

course of a few years, even though they were originally expensive.

This is not the place to discuss the advantages of various filtration schemes, first because it would take us far beyond our reasonable limits, and, further, because your engineers have covered or are about to cover all such questions so far as they apply to the special wants of your city; but let me leave this one additional thought with you, using the statistics as given above.

Suppose some public undertaking (the much-accused trolley system, for instance) were so badly managed that 523 human lives were crushed out annually and some 4,707 other persons were more or less seriously injured, do you suppose that the good people of Philadelphia would tolerate such a state of affairs, or that they would grudge the amount of money necessary to stop such carriage? Surely not; yet they are submitting quietly to just as large a loss from death and disability, only it comes in a way less tangible and less shocking to the feelings.

There is, believe me, no system of filtration, or other efficient method for purifying a polluted water, so expensive but that a community can well afford to introduce it rather than to drink a dangerous water in its raw state, and this, too, from purely economic considerations, and leaving out of sight all ethical questions whatsoever.

Without wishing to "thrash old straw," let me ask such as may have doubts upon this point to read again the history of the epidemic of typhoid fever in the valley of the Tees, and the records of the late cholera plague at Hamburg, and to note what such dire experiences have taught and what use has been made of the teaching.

Finally, let us inquire, do those interested in the furnishing of water to a town ever permit a factor to enter their calculations representing the pecuniary damages that might be claimed by parties who receive bodily injury through the use of impure water? This question appears to be assuming some magnitude just at present, and if the courts look favorably upon it, there is scarcely a limit to the proportions it might assume. Sundry suits are now pending in the West

to recover the legal value of human life alleged to have been destroyed by typhoid fever, contracted by the use of impure water. Such suits are based upon evidence tending to show that the public waters in question are seriously polluted by sewage, and are consequently sources of disease.

Fancy, if you will, what a disturbance would ensue in water circles should these plaintiffs gain their causes. Precedents would be established that might well carry financial ruin to many a corporation, whether public or private, and figures of such size for damages would be added to those representing yearly loss already given, as would make the most conservative member of the Board of Water Commissioners admit very candidly that cheap water may be at times a poor investment.

THE FRANKLIN INSTITUTE.

Stated Meeting, held Wednesday, March 17, 1897.

JOHN BIRKINBINE, President, in the chair.

IMPROVED SAFETY DEVICE FOR ELECTRIC CIRCUITS.

BY LEWIS G. ROWAND.

The demand for some means of protection against the dangers that arise from the accidental breaking and grounding of heavily charged overhead wires, has brought forth various devices to accomplish this end.

My method of reducing the element of danger arising from this source is to open the circuit at the instant the wire breaks or becomes short-circuited.

While this principle can be used on any electric circuit, it is particularly well adapted on electric railroad circuits, and it is in connection with this line of work that I have prepared an exhibit which will enable me to give you a practical illustration of its application.

I will show, by aid of certain models and drawings, different applications of my device to meet the various requirements of electric trolley circuits.

In order to make the following explanation as comprehensive as possible, I have prepared drawings of each model, having all parts lettered, to correspond with such parts shown thereon.

In the drawings, *Fig. 1* is a diagram of a single line, and of the wiring of Board No. 1.

Fig. 2 is a diagram of a single line, and of the wiring of Board No. 2.

Fig. 3 is a diagram of a double line, and of the wiring of Board No. 3.

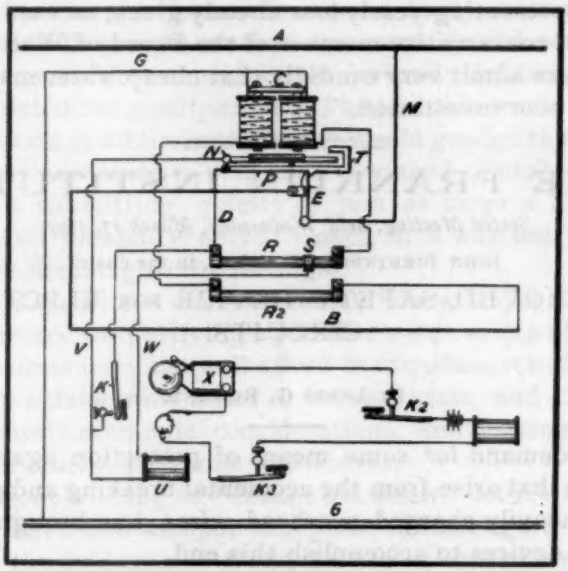

FIG. 1.—Diagram showing single section with alarm circuit.

Fig. 4 is a diagram of two sections of a single line and of the wiring of Board No. 4.

Referring to *Fig. 1* and Board No. 1, *A* is the main feed, or trunk wire, *B* the trolley section. The return of this trolley section, *B*, before passing to ground, passes through the resistance, R^2, and the electro-magnet, *C*, which has double windings, the winding being such that when current passes through both windings, one neutralizes the other and consequently there is no magnetic result, and the magnet is not energized. The trolley section, *B*, passes to one

of these windings; a wire, *G*, is connected to rail; *D* is a wire, connected also with the trunk line through switch contact and to the other winding of the magnet, *C*, the trolley section, *B*, and wire, *D*, having a common connection with the trunk line, *A*, through wire, *M*. The wire, *D*, is connected, through resistance, *R*, with the opposite winding of the magnet, *C*, of that to which wire *B* is connected. Thus it will be seen that the circuits formed by wire, *B*, and wire, *D*, have a common connection with the trunk line, *A*, through wire, *M*, with the source of current supply (trunk, *A*), common to both, each circuit having a winding of the magnet, *C*, in circuit; but the windings are such that when current passes through both windings, the two circuits neutralize each other, and the magnet is not energized. Upon the connection, *M*, common to both circuits, *B* and *D* is switch, *E*, which switch is normally closed and is controlled by armature, *N*, of the magnet, *C*.

It is desirable that the least possible amount of current should pass to the magnet, *C*, through the currents, *B* and *D*. This is accomplished by making the resistances *R* and R^2 very high, as is here shown. At 220 volts, we have, in circuit *B*, 3,000 ohms, taking ·073 ampère. In circuit *D*, we have also 3,000 ohms, taking ·073 ampère. Combined resistance 1,500 ohms; total, ·146 ampère; or 32·12 watts consumed at each switch.

Under these conditions, when the magnet becomes energized it is but slightly so, and therefore would not be strong enough to trip the switch, which must, necessarily, have a powerful spring to ensure opening the switch quickly. I, therefore, provide the following lever, *P*, instead of being acted upon direct, through the medium of pivoted lever, *N*, which forms the armature of the magnet, *C*. The lever, *P*, has a projection, *T*, in the line of movement of one end of lever, *N*. Both levers, at this point, carry contact points normally out of contact with each other. A wire from one side of resistance, *R*, in circuit, *D*, passes to lever, *P*, and from sliding contact, *S*, on resistance, *R*, a wire passes to lever, *N*, through signal magnet, *U*.

Now suppose the circuit, *B*, to become broken. First, the

magnet, *C*, is energized by the slight amount of current in circuit, *D*, passing through resistance, *R*, which is enough to attract the armature, *N*, so that the contact on it, and that of lever, *P*, are brought together, thus allowing the current in circuit, *D*, to pass to the magnet, *C*, through wire, *V*, through magnet, *U*, through wire, *W*, to sliding contact, *S*, through a portion of resistance, *R* (which can be adjusted to the necessary amount of current required to operate the switch), through wire, *D*, drawing up lever, *N*, so that it, acting on the projection, *T*, of lever, *N*, draws up the lever which trips the catch, allowing switch, *E*, to open the circuit. At the same time, the current passing through magnet, *U*, of the signal device releases the mechanism and signals the number of the box (which is in this case No. 87) to the station or repair wagon, or both. This signal passes over an independent circuit, preferably a closed metallic circuit, such as is used for fire-alarm. We can, by using key, K^3, signal to Station, also receive signals from Station on gong, *X*.

If repair wagon should be at box No. 87 when another switch on the same signal circuit opens, the men would hear the number of the switch thus opened tapped on the gong, and could go directly to the point without returning to the Station. If the presence of the repair-men were required to answer a signal received from another circuit at Station, while attending to a previous call, they may be notified of the last call from Station by giving the required number of taps over the circuit on which they are at work. The signal movement can also be started by hand without the opening of the switch. A telephone connection can be made in each box, permitting conversation between each box and Station. There is also included in each box a signal key, *K*, which is a very important feature of the system. In the event of a fire, the policeman, fireman or trolley employee can, by opening the signal-box and pressing key, *K*, open the switch and notify Station at the same time. The wire in that section is then dead and the firemen need lose no time in getting at work. After the fire, there will be no delay in repairing the line, as there are no cut wires

to splice. All that is necessary is to close the switch and the line is ready for the cars.

In *Fig. 2* and Board No. 2, the arrangement of switch and

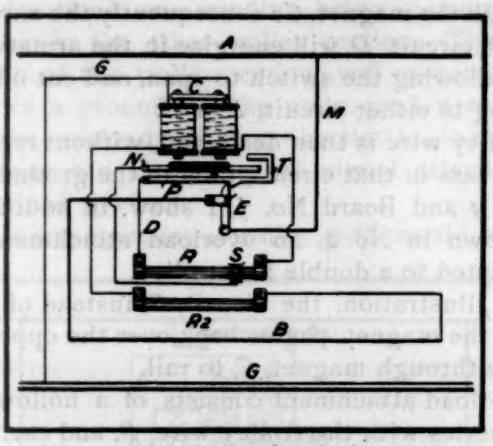

FIG. 2.—Diagram showing single section.

circuits are identical with that of No. 1, which I have just described, except that the signal device is omitted.

The practical operation of this switch may be thus

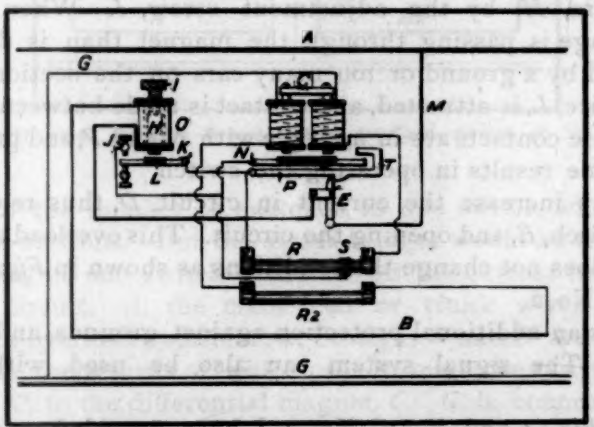

FIG. 3.—Diagram showing double trolley with overload.

described: Under ordinary conditions, the current passes from the trunk line, *A*, through both the circuits, *B* and *D*. The circuit, *B*, feeds the trolley wire. Both circuits, *B* and

D, pass through the magnet, *C*, but in such directions as not to energize it. Now, if the trolley wire, *B*, should break, the current will no longer, as far as that circuit is concerned, pass through the magnet, *C*; consequently the currents passing through circuit, *D*, will energize it, the armature will be attracted, allowing the switch to open, and cut off any current passing to either circuit, *B* or *D*.

The trolley wire is then dead, and, without regard to the number of cars in that circuit, falls to the ground harmless.

In *Fig. 3* and Board No. 3 I show, in addition to the devices shown in No. 2, an overload attachment and the switch adapted to a double line trolley.

In this illustration, the circuit, *B*, instead of returning directly to the magnet, passes back over the opposite track, and thence through magnet, *C*, to rail.

The overload attachment consists of a hollow spool, *O*, wound in series with the trolley wire, *B*, and carries all the current passing to the trolley wire. I have provided means whereby the switch may be adjusted to carry any desired ampèrage. *H* is a sliding core, fastened to an adjustment screw, *I*. The adjustment is reached by raising or lowering the core, *H*, by the adjustment screw, *I*. When more ampèrage is passing through the magnet than is desired (caused by a ground or too many cars on the section), the armature, *L*, is attracted, and contact is made between *J* and *K*; these contacts are in multiple with *N* and *P*, and produce the same results in operating the switch.

They increase the current in circuit, *D*, thus releasing the switch, *E*, and opening the circuit. This overload attachment does not change the conditions as shown in *Fig. 2* and Board No. 2.

It is an additional protection against grounds and overloads. The signal system can also be used with this device.

In *Fig. 4* and Board No. 4, I have provided a switch which is practically a differential-wound relay, to have special contacts in practice to carry heavy currents for a short time. It will be seen that with all the different relay devices used in these switches, I always *make* contacts and

do not *break* them. The current is always thrown off at the switch.

This relay has two windings, the same as in the switches heretofore described; one winding being in one trolley section, the other in the other trolley section. The breaking of either one of the trolley sections will operate the relay, which throws a ground on the main feed wire, *A*, which will cause the overload switch at the station to open.

(This device can also have the signal attachment, but not the overload device.)

With this arrangement a trolley road would require but

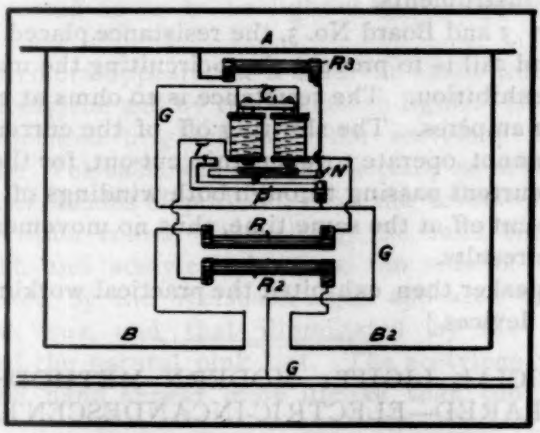

FIG. 4.—Diagram showing two sections, overload switch at Station for economy.

one-half the number of switches, as one switch will operate two sections. But the disadvantages would be that the operating of one switch would cut off the current from the entire circuit. *A*, the main feed or trunk wire, passes through overload switch, *O*, at Station; *B* and B^2 are trolley sections, the returns of which pass through the resistances, *R* and R^2, to the differential magnet, *C*. *G* is connected to rail or return. Now, suppose the circuit, *B*, to be broken, the current will then cease to flow through winding, *B*, of the magnet, *C*, and the magnet will be energized by the current passing through circuit, B^2. This will attract armature, *N*, and make contact, *T*, and close circuit with con-

tact, *P*, through wire, *G*, to rail through resistance, R^3. (This resistance is used for this special occasion to prevent short-circuiting the mains.)

This resistance is 12 ohms at 220 volts, giving $18\frac{1}{3}$ ampères. This operation will throw the overload switch, *O*, at the Station and open the entire circuit. In the event of circuit, B^2, becoming broken, the action is exactly the same.

This device will reset itself after throwing the overload switch at Station.

The cut-outs and devices exhibited here to-night were built for experimental purposes, and are not calculated for standard instruments.

In *Fig. 3* and Board No. 3, the resistance placed between trolley and rail is to prevent short-circuiting the mains during this exhibition. The resistance is 10 ohms at 220 volts, giving 22 ampères. The shutting off of the current at the station cannot operate to open this cut-out, for the reason that the current passing through both windings of magnet, *C*, will be cut off at the same time, thus no movement of the armature results.

[The speaker then exhibited the practical working of the different devices.]

ARTIFICIAL LIGHT: MODERN METHODS COMPARED—ELECTRIC-INCANDESCENT, WELSBACH, ACETYLENE.*

By Prof. D. S. Jacobus,
Stevens Institute of Technology, Hoboken, N. J.

[The lecture was introduced by experiments to show the appearance of various colors when viewed by the different lights. Two surfaces of the same color were held up at an angle between two sets of lights, each set containing eight lamps or burners. The two sets of lights to be compared were placed at a distance of about 6 feet from each other on the lecture table. Screens were placed in front of the burners, to shield the eyes of the audience

* A lecture delivered before the Franklin Institute, March 12, 1897.

from the direct glare of the lamps. In the space between the lamps colors were shown on large pieces of cardboard, doubled over at the middle so that the two sides could be held at an angle to each other. This allowed one surface to be illuminated by one set of lamps, and one by the other. The audience could observe each surface at the same time, and thus compare the colors as they appeared to the eye.

A second series of experiments consisted in viewing colors of a slightly different hue, which appeared of nearly the same hue when held in one position between two sets of lamps, and of a widely different hue when the colors were reversed so as to be lighted by the opposite set of lamps.

Many colors appeared of a different shade when viewed by the acetylene and by the Welsbach lights. Some of the colors appeared brighter under the acetylene light than under the Welsbach, and this is especially so in the case of the lighter shades of pink, whereas the reverse holds true of some other colors. On holding the hand between the Welsbach and acetylene burners, the side of the hand illuminated by the Welsbach light appeared to be of a yellowish hue, and that illuminated by the acetylene exhibited the natural pink tint. The acetylene, therefore, made the hand appear more lifelike than the Welsbach light.

Ordinary gas, and the incandescent electric light also produced more lifelike tints when the experiment was made of holding the hand between them and a Welsbach lamp.

Experiments were described, which had been made before the lecture, in which the apparent tints, when viewed by the different lights, were compared with the tints when the colors were viewed by daylight. The acetylene flame was found to show the light pinks or flesh colors much more nearly in their natural tints, or their colors when viewed by daylight, than the Welsbach. The same results followed for incandescent electric light and ordinary gas, when burned in a flat flame, both of which brought out the lighter shades of pink more truly than the Welsbach. The experiments demonstrated that there is

a very slight difference in favor of the acetylene over the incandescent light in bringing out delicate shades of pink, and that ordinary gas burned in a flat flame burner comes next in this respect.

Some colors other than pink were found to appear more nearly of their true tints under the Welsbach than under the other lights, in the experiments where the lights were compared directly to daylight.]

CANDLE-POWER DEVELOPED PER CUBIC FOOT OF GAS. ELECTRICAL ENERGY TO PRODUCE THE ELECTRIC LIGHT AND PROPORTION OF TOTAL ENERGY TRANSFORMED INTO LIGHT. ALSO, RELATIVE HEATING AND CONTAMINATION OF THE ATMOSPHERE BY CARBONIC ACID FOR EQUAL CANDLE-POWERS.

The figures for the various methods of illumination are given in Table I, in order that they may readily be compared.

TABLE I.

Kind of Light.	Candle-power of Gas on the 5 Cubic Feet per Hour Basis.	Gas Required per Hour for 16 Candle-Power in Cubic Feet.	Heat of Combustion of Gas in B.T.U. per Cubic Foot at 60° F.	Total Heat in B.T.U. for 16 Candle-Power per Hour.	Percentage of Total Heat Converted into Light.	Cubic Feet of CO_2 Produced by a 16 Candle-Power Light per Hour.
1	2	3	4	5	6	7
Illuminative Water Gas. Flat flame burner . . .	20	4·00	700	2,800	0·6	3·4
Illuminative Water Gas. Welsbach . . .	70	1·14	700	798	1·9	1·0
Acetylene	200	0·40	1,420	568	2·7	0·8
Incandescent electric	—	—	—	250	6·2	0·0

It will be seen, from the figures given in Table I, that acetylene gives ten times as much light as ordinary illuminating water gas when the latter is burned in a flat flame burner, and about three times as much when the latter is burned in a Welsbach burner.

The percentage of the total heat of combustion of the gas

transformed into light is also greater for the acetylene than for the ordinary illuminating gas. For a given illumination the atmosphere is vitiated by the carbonic acid formed in burning the acetylene to a slightly less extent than when burning the ordinary illuminating gas in a Welsbach burner.

The figure for the candle-power of the gas on the basis of 5 cubic feet burned per hour, given in Table I, is from my own experiments. The figure for the Welsbach is derived from the results obtained in tests of both old and new mantles on the latest form of lamp, and is safe for ordinary practice, as it is nearer to that obtained with old mantles than to the results obtained with the new.

The candle-power given in the table is an average of the candle-power in a horizontal plane passing through the lamp center. The spherical candle-power is less than the candle-power so measured, but the proportion between the spherical candle-powers would be about the same as the proportion between the candle-powers measured in a horizontal plane, or within the range of variation of the experimental results; so that comparative figures may be obtained by using the latter.

SAFETY. EXPLOSIVE PROPERTIES OF ACETYLENE.

If 3 per cent. of acetylene be mixed with air, an explosive mixture is produced. In the case of hydrogen 5 per cent. is required, and for coal gas 8 per cent. The maximum amount of acetylene that can be mixed with air to form an explosive mixture is 82 per cent., and the corresponding figure for hydrogen is 72 per cent.

It, therefore, appears that acetylene is more explosive than either hydrogen or coal gas. As the burners used for acetylene would discharge a less amount of gas—say one-fifth that of an ordinary gas burner—the accidental opening of a burner would cause the atmosphere of the room, as a whole, to be much less contaminated in a given time than with coal gas. On the other hand, acetylene gas is so much more nearly of the density of air than ordinary illuminating gas, that it will not be diffused as rapidly through the air

in case of leakage, and will have a greater tendency to collect in a partly enclosed space, and thus cause an explosion in case the gas were ignited.

[Experiments were made in which acetylene and ordinary illuminating gas were exploded when mingled with air. The gas was allowed to escape from a burner into a tube placed at an angle. The explosion produced by the acetylene was much more severe than that produced by the illuminating gas.]

In regard to the explosive properties of acetylene itself, much may be said. When carbon and hydrogen unite to form the compound called acetylene, heat is absorbed. According to Berthelot, if gaseous acetylene, under a pressure of about 15 pounds above the atmosphere, or over, be ignited by a spark, or by a heated platinum wire, it will decompose explosively without the presence of air. The explosion becomes more violent as the initial pressure is increased. In exploding, the carbon and hydrogen are dissociated, and the heat absorbed in the original formation is set free. This heat, according to Berthelot, is sufficient to increase the temperature (provided the pressure be kept constant), about 5,000 degrees Fahrenheit, or to increase the pressure to eleven times the initial (if the volume be maintained constant). At atmosphere pressure, however, Berthelot found that acetylene gas containing no air could not be exploded; for if a spark were generated in it, or even if fulminate were exploded in it, there would be no decomposition into the elements of carbon and hydrogen, except near the point where the spark, or fulminate, acted on the gas.

Berthelot also found that liquid acetylene, as transported in tanks under pressure, would explode as readily as the gas. In one case, he exploded liquid acetylene in an iron tank by means of fulminate of mercury, and shattered the tank to pieces. He also made experiments to determine if blows or shocks would start explosions in cylinders of the liquid. He found that a shock would not of itself start an explosion, but that when steel cylinders of the liquid acetylene were smashed, the blow was usually followed by an explosion,

probably produced by the sparks generated by the friction of the pieces of broken steel. He states that local elevation of temperature may produce compounds evolving heat, and finally cause an explosion; and also that the sudden opening of a stop-cock may produce local heating and an explosion.

The investigations of Berthelot on the explosive properties of acetylene show how dangerous the gas is when stored under pressures higher than that of the atmosphere. That such is the case is borne out by the fact that a number of accidents have occurred where it has been used under such conditions.

In the Pictet works, in Paris, acetylene is compressed in steel cylinders that have previously been tested to 250 atmospheres. A short time ago a cylinder of this description, of large capacity, exploded at the Pictet works, killing two workmen and injuring another. The two men were torn to pieces, and a part of the works was blown down.

There is another case on record where a cylinder of acetylene, fitted up to light a dwelling-house, exploded and seriously injured a tinman and his laborer, who were at work upon the premises.

An explosion of liquid acetylene, resulting in the death of four persons, took place in a Berlin suburb some time in last December. This explosion occurred at the time when a chemist named Isaac, who had for some time experimented with acetylene with a view of depriving it of its dangerous qualities, was preparing an exhibition of the results of his experiments, a record of which was to be presented to the German Emperor. The use of acetylene is prohibited in Germany, owing to its explosive character, and it was to deprive it of its dangerous qualities that Mr. Isaac made his experiments, and thereby met his death.

By an explosion of a cylinder of liquid acetylene at New Haven, in January, 1896, three persons were killed and four injured. The explosion occurred while experiments were being made on a regulator to reduce the pressure in the tanks to that required at the burners.

An explosion occurred in Jersey City about one year ago,

when it was attempted to generate the gas from the carbide under pressure. This shattered the roof of the building, the apparatus being in the upper story, and demolished the woodwork in the neighborhood of the generator; but fortunately no one was near enough to the generator at the time of the explosion to be seriously injured.

All the above explosions are cases in which the acetylene was under pressure, and exploded in the same way as ordinary dynamite or gunpowder; that is, by the decomposition of its own elements without the aid of the oxygen of the air. There have been accidents, however, where it is probable that the explosions were caused by the mixture of air with the acetylene.

For example, an accident took place at Lyons a few months ago, in a café lighted by acetylene generated on the premises. The explosion produced much damage, and killed two persons.

Another explosion, or, perhaps, it might be called a case of accidental ignition of the gas, occurred in Jersey City last January. The liquid acetylene was being blown from a tank into a felt bag, in order to obtain solidified acetylene, or snow, in the same way that snow may be obtained from carbonic acid. An explosion of the escaping gas occurred, which set fire to the mass of solidified acetylene. One of the workmen was severely burned about the face and hands.

In view of the above practical demonstration of the danger of acetylene gas under pressure, it would seem unwise to use it in that way; and even when generated on the premises at atmospheric pressure great precautions should be employed to prevent explosion, on account of the admixture of air.

RELATIVE COSTS FOR EQUAL ILLUMINATION.

The costs per hour for a production of 16 candle-power of light, in the city of New York, are shown in Table II:

TABLE II.

		Cents.
Incandescent electric light at 1 per cent. per lamp hour		1·0
Illuminating water gas.	Ordinary burner, 4 cubic feet, at $1.25 per 1,000 cubic feet	0·5
	Welsbach burner, 1·14 cubic feet at $1.25 per 1,000 cubic feet	0·17
Acetylene employed for Municipal distribution.	Calcium carbide, furnished to gas company and converted into gas for $40 per ton* . .	0·5
	Calcium carbide, furnished to gas company and converted into gas for $19.50 per ton† .	0·17

* To replace flat-flame burners.

† To replace Welsbach, cost of replacing mantles of Welsbach lamps included in the estimate.

The price at which calcium carbide would have to be furnished for domestic lighting, to be as economical as kerosene oil at 8 cents per gallon, is $45 per ton. The compressed liquid acetylene would have to be furnished for 6½ cents per pound to be as economical as kerosene.

It will be seen from Table II that to compete with an ordinary illuminating water gas selling at $1.25 per 1,000 feet in municipal distribution, the carbide would have to be furnished to the gas company and converted into gas for $40 per ton, to net the gas company the same profit, and to be as economical to the consumer as the ordinary illuminating gas burned in the flat-flame burner. To be as economical to the consumers as ordinary gas burned in Welsbach burners, it would have to be furnished to the gas companies and converted into gas for $19.50 per ton.

It is further shown that, to be as cheap as kerosene in domestic lighting the carbide would have to be supplied to the consumer at $45 per ton, and the compressed liquid acetylene would have to be supplied at 6½ cents per pound.

The figure for the Welsbach burner in Table II is obtained by adding to the cost of the gas 0·03 cents per hour per 16 candle-power to replace mantles, which are assumed to cost 50 cents, and last 500 hours on a lamp furnishing 50 candle-power. The difference in cost in favor of the Welsbach will disappear to a great extent in practice; for if ordinary gas burners are replaced by the Welsbach, the total amount of illumination, as a rule, becomes greater, and if

three times as much, the cost of gas to the consumer per month would be the same with the Welsbach as with the ordinary gas burners.

The figures for the acetylene are obtained in the following way:

Assume a plant which is furnishing an illuminating water gas at $1.25 per 1,000 cubic feet. If this plant were converted into a plant to furnish acetylene gas, there are certain expenses, such as the cost for distribution, including the maintenance of the plant, collection of bills, office expenses, etc., that would remain about the same per day for the acetylene as for the water gas. These constant expenses would practically be all other expenses, except those involved in making the gas and storing it in the holder. To simplify matters, let us consider a plant of any given capacity, say, 500,000 cubic feet of gas per day. Then we have:

Paid by consumers per day, 500,000 cubic feet, at $1.25 per 1,000 cubic feet	$625 00
Cost of gas in holder, at 40 cents per 1,000 cubic feet*	200 00
Constant expenses per day, together with profit of gas company	$425 00

* The cost of gas stored in the holder is less than 40 cents per 1,000 cubic feet in many large plants, and the price that the gas companies could afford to pay for the carbide would be proportionally reduced. For example, if the gas were stored in the holder for 30 cents per 1,000 cubic feet, the carbide would have to be furnished to the gas company and converted into gas for $30 per ton, to be as cheap as ordinary gas burned in flat-flame burners.

To furnish the consumers with the same amount of light that they obtained with the flat-flame burners and the ordinary illuminating gas, would require one-tenth the volume of acetylene, hence one-tenth of 500,000, or 50,000 cubic feet of acetylene would have to be stored in the holder for $200, in order that there should be the same profit to the gas company. This 50,000 cubic feet would be produced by 5 tons of calcium carbide; hence, the cost of 1 ton of calcium carbide, together with the cost of converting the carbide into gas, would be $40, to compete with ordinary gas at $1.25 per 1,000 cubic feet, burned in flat-flame burners.

To compete with ordinary gas burned in Welsbach burners, the amount of acetylene stored in the holders would be in the ratio of 70 to 200 to the amount of ordinary gas re-

quired for equal illumination; or, we would have to store 175,000 cubic feet in the holder for $200. In addition to this, the cost of the mantles replaced per day in the Welsbach lamps should be included, which would be $140, making a total of $340. To produce the 175,000 cubic feet would require 17·5 tons of calcium carbide, and it would have to be furnished at the gas works and converted into gas at about $19.50 per ton.

It may be claimed that to replace ordinary gas in an existing plant by acetylene would be making use of a plant much too cumbersome for the purpose, and that the interest on capital investment and depreciation would count more heavily against the acetylene than in a plant specially constructed for the purpose. On the other hand, in a plant specially constructed for acetylene, the system of mains for transmission of the gas would have to be laid with much more care than for ordinary illuminating gas, and special piping might have to be used, so that the capital investment of a specially constructed acetylene gas plant might be as much or more than for one furnishing ordinary illuminating gas.

If one-tenth as much acetylene were used for a given illumination as with the ordinary gas, then, if transmitted through the same system of pipes, the percentage of leakage, based on the amount of gas used by the consumers, would be increased about tenfold; or, if the percentage of leakage in a system had been 5 per cent. with ordinary gas, it would be about 50 per cent. with acetylene, of the gas used by the consumers, or 33 per cent. of the gas stored in the holder.

The system of piping now in place for ordinary illuminating gas would not, therefore, be suitable for the transmission of acetylene gas. If special pipes were laid for the acetylene gas they would be required to carry a less volume of gas for a given illumination, and could be made smaller, but it is probable that the care required to produce tight joints would make it just as expensive to lay them as to lay the pipes for ordinary illuminating gas.

Let us next consider the price calcium carbide must be

sold at to take the place of kerosene in domestic lighting, where the gas is generated on the premises. Assume that the cost of labor to charge the gas generator, and depreciation of the plant, is equal to the cost of labor to fill and repair the oil lamps; then we have to compare the cost of the carbide with the cost of kerosene oil required to produce an equal illumination. It was found by my own experiments that to produce 16 candle-power in an argand, or in a good flat flame lamp required about 0·022 gallons of oil per hour. At 8 cents per gallon this would cost 0·18 cents. To produce 16 candle-power with acetylene requires 0·4 cubic feet of gas per hour, so that 0·4 cubic feet would have to be produced for 0·18 cent, or 10,000 cubic feet for $45. Hence, the carbide would have to be purchased for $45 per ton to be as cheap for equal illumination as kerosene oil. As one pound of the compressed liquid acetylene produces about 14½ cubic feet of gas, it would have to be sold for 6½ cents per pound to be as cheap for a given candle-power of light as kerosene.

In some of the earlier literature on acetylene it was proposed to convert electric lighting plants into plants for the production of acetylene, and thus obtain economic results. This could not be done economically, for only about one-half as much light could be obtained from the acetylene as by using the electricity direct for incandescent lights. The results obtained at Spray show that 2 cubic feet of acetylene gas could be produced per hour per electrical horse-power. This would furnish $2 \times 40 = 80$ candle-power. If the electricity were used direct with incandescent lamps requiring 4½ watts per candle-power, the light produced would be $746 \div 4{\cdot}5 = 166$ candle-power per electrical horse-power, or about twice as great a light as would be produced by the acetylene, as has already been stated.

To be as cheap an illuminant as electricity, therefore, the carbide must be made at some point, say, a water-power, where the cost of the power and attendance is much less than at the lighting station.

It has been shown that for an equal illumination the electric incandescent light costs twice as much as gas when

the latter is burned in flat-flame burners. The incandescent electric light has, however, held its own against the gas light on account of its superior qualities, which are its brilliancy, cleanliness and adaptability. The electric light is also preferable on account of the fact that it does not vitiate the atmosphere with carbonic acid gas, and that it produces a less heating effect than ordinary illuminating gas. It also eliminates the danger of asphyxiation through an accidental leakage of gas. That the incandescent electric light has held its own at a higher cost to the consumer for a given candle-power, is a proof that other elements enter into the problem of artificial lighting as strongly as the cost of a given amount of light. From this standpoint, it may be argued that acetylene, producing as it does a more brilliant light than any now used for interior lighting, and having the quality of showing the complexion in life-like tints, will have its own field, even should it be the most costly style of illumination.

Again, acetylene is now used in place of the calcium light for lantern projections, etc. Were it not for the explosive character of the compressed acetylene, it would be useful for cases of isolated lighting, such as for beacons and light-buoys.

It has also been shown that the Welsbach lamp produces about three times the illumination for a given cost as ordinary illuminating gas burned in a flat-flame burner, but that it is deficient in showing the complexion in lifelike tints. For most classes of work, this defect is not of great enough importance to outweigh the advantage derived from its great economy.

The whole situation may be summed up by saying that each system of lighting has its own field of usefulness, on account of properties peculiar to itself, which make it more desirable than the others for certain classes of work.

REPORT OF TESTS OF A 28-INCH AND 36-INCH "CASCADE" WATER WHEEL MADE AT THE MECHANICAL ENGINEERING LABORATORY OF THE OHIO STATE UNIVERSITY.

ABSTRACT BY JOHN H. COOPER.

As a matter of general information, supplementing the very elaborate communication on the historical development of the type of water wheels known as the "tangential" or impulse water wheel, which was lately published in this *Journal*,* the following record of tests of the efficiency of a modified form of the tangential water wheel, manufactured by James Leffel & Co., Springfield, O., which were made in the mechanical engineering laboratory of the Ohio State University, under the direction of Prof E. A. Hitchcock, Director, will be found to make an interesting contribution to the history of this class of machines.

A brief description of the "Cascade" wheel is introduced, to give the reader an idea of its distinctive features. It is adapted, like others of its class, for use where small quantities of water under very high heads are available.

This wheel has two separate sets of buckets. These buckets are located alternately on each side of a central, sharp, continuous, dividing ridge, projecting a little in front of the entering edge of the buckets. This dividing ridge has a sharp, cutting edge, which serves to divide the jet of water before it touches or reaches the buckets, and to keep it continuously divided in two equal portions, so that each portion of this single jet is received separately on each side of the dividing ridge. One-half of the jet is therefore received by one series of buckets independently of the other half, which is received by the other series. Each series of buckets on each side of this continuous dividing edge is so arranged that no two come opposite each other, and, as a consequence, the buckets of each series catch the water alternately.

The claim is made for this alternating arrangement of buckets that it secures greater steadiness of motion, since

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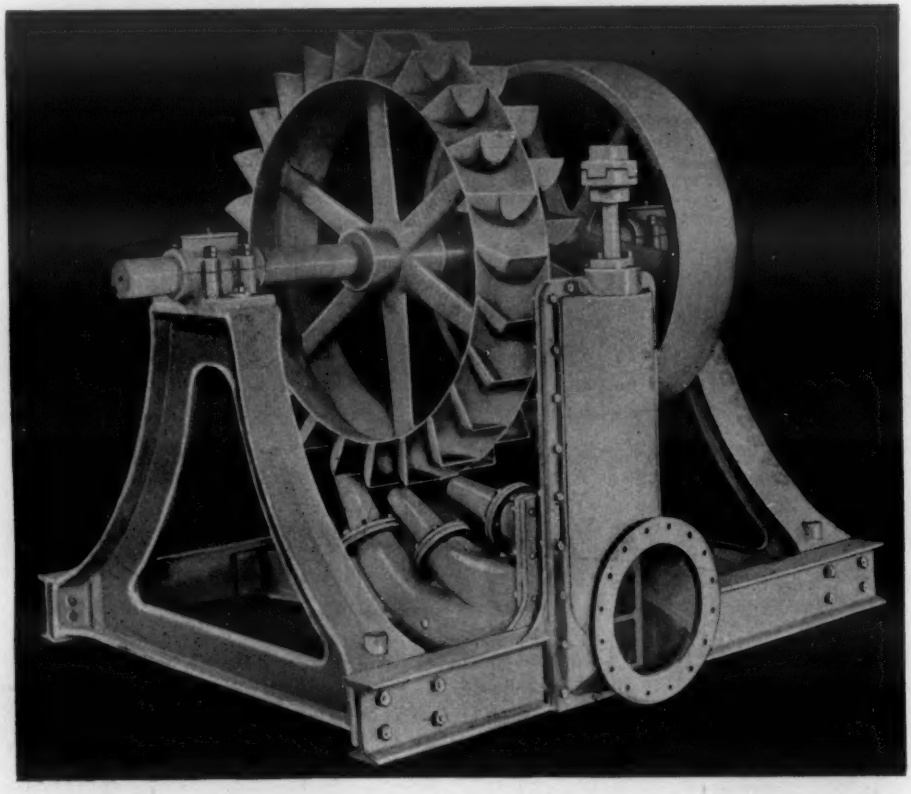

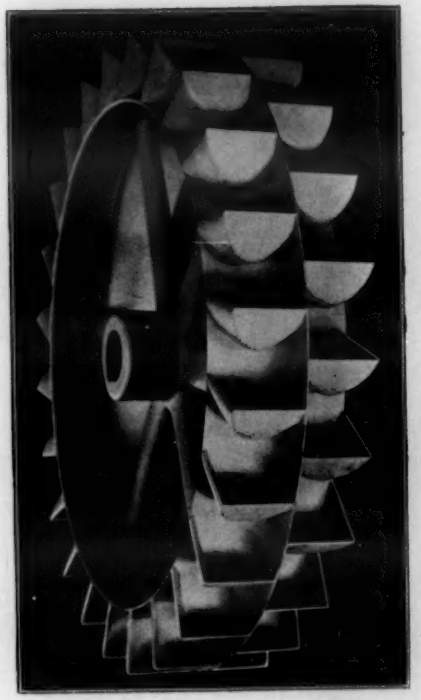

"CASCADE" WATER WHEEL.

it is equivalent to twice the number of buckets, and the impulses are therefore divided more regularly on the wheel, as each bucket passes the point of the nozzle, and catches its half portion of water. These buckets are cast solidly upon each side of the circular dividing ridge and upon the face or rim of the wheel on each side of this central division. This circular ridge being also angular and curved as it approaches the center, gives to the interior of the buckets a symmetrical and effective curve. The further claim is made by the builders that this arrangement of buckets and form of construction secure great strength, firmness and stability, and the buckets are not subject to the difficulty of becoming loose, as those styles in which bolts, nuts and other appliances are used to fasten them upon the face or rim of the runner.

The illustration shown herewith gives a perspective view of the wheel, showing clearly the alternate arrangement of the buckets, and also a view of the wheel mounted in an iron frame and with the side and top of the casing removed, by which the mode of admitting the water through several jets or nozzles is seen. While these nozzles constitute really one piece, the water is admitted separately to each, and the entire system of nozzles is easily set and fastened within the casing upon a light and planed joint. The mode of mounting is such as to permit of moving these jets and thereby varying the inclination at which the water may be projected upon the buckets. Either of the tips or nozzles may be removed, and others, of different size or bore, put in their places, or any of them may be capped over, and one or several or all used as may be desired.

By a modification of the casing or framework, three or more additional jets may be added, extending the stream further around the circumference of the wheel. The usual requirements, however, of this class of wheels will be limited to one, two or three jets, and the number of these and the style of mounting are modified to suit the conditions of each case.

The following table gives the results of a series of tests of this wheel made in the summer of 1896, in the mechanical

engineering laboratory of the Ohio State University, Columbus, O.

It will be observed that there are six tests given on each of two wheels of different sizes running at different speeds. The slight variation in efficiency is attributed to this difference in the number of revolutions.

EFFICIENCY TESTS.

	Head in Pounds.	Head in Feet.	Flow of Water in Pounds per Minute.	Revolutions per Minute.	Brake Load.	Developed Foot-Pounds of Work.	Developed Horse-Power.	Foot-Pounds of Work Expended by Water.	Efficiency.	Velocity of Wheel.
38" Wheel.	75·35	165·3	3,330	309·8	80	495,680	13,662	550,400	90·04	47·75
	71·10	164·2	3,318	331·2	75	496,800	15,054	514,600	91·02	50·83
	71·75	165·7	3,335	273·6	90	492,480	14,924	553,500	89·16	41·66
	63·92	147·7	3,135	337·0	60	404,400	12,254	463,000	87·34	52·08
	67·25	155·3	3,222	336·0	65	436,800	13,236	500,350	87·30	52·02
	67·95	157·0	3,238	316·2	70	442,680	13,414	508,350	87·06	48·75
26" Wheel.	70·15	160·0	3,075	492·8	30	283,680	8,778	331,980	87·23	49·80
	70·75	163·4	3,085	447·0	35	312,900	9,482	340,689	91·85	46·20
	70·35	162·5	3,078	377·4	40	301,920	9,149	337,675	89·40	37·95
	71·35	164·8	3,324	491·8	50	491,800	14,903	560,400	87·76	50·90
	71·95	166·2	3,340	445·2	55	489,720	14,840	555,108	88·20	46·25
	70·65	163·2	3,309	400 0	60	480,000	14,545	540,000	88·88	41·50

Great care was taken in making the preparations for these tests and in conducting them, and the authors believe that the results announced may be accepted as thoroughly accurate and reliable. The average efficiency in each case, it will be observed, is very high.

These tests were made by Messrs. L. A. Frayer, Maurice Donham and Raymond Cilley, of the senior class of the University, under the supervision and inspection of Prof. E. A. Hitchcock, head of the mechanical engineering department. J. H. C.

CHEMICAL SECTION.

Stated Meeting, Tuesday, March 16, 1897.

Dr. Jos. W. Richards, President, in the chair.

RELATIONS BETWEEN THE MELTING POINTS AND THE LATENT HEATS OF FUSION OF THE METALS.

By Joseph W. Richards, Ph.D.

In a lecture before this Institute in January, 1893, on "The Specific Heats of the Metals," I announced the fact that in the case of most of the metals whose latent heats of fusion were known, this quantity bears a simple relation to the heat required to raise the metal from absolute zero (— 273° C.) to its melting point. In most cases the former is one-third the latter. I even ventured to predict that the latent heat of fusion of gold was about 14 calories, and it has since been determined by Roberts-Austen as 16·3. Further, several latent heats have since been determined which conform to the above relation, and I have thought it opportune to collect these data and point out the limits of the relation, with some other observations which later thought on the subject has developed.

In the following table there is given, first, the heat required to raise 1 kilogram of the metal from the absolute zero to its melting point (using the most probable values for the specific heats and exterpolating to — 273°, for a discussion of which data reference is made to the paper already quoted); second, a simple fraction of this quantity and, lastly, the actually determined latent heats of fusion, the experimental errors of which are probably 5 to 10 per cent.:

Element.	*Heat Absorbed from −273° C. to the Melting Point.*		*Latent Heat of Fusion (Experimental).*
Sodium	107·8	⅓ = 35·9	32·7
Aluminium	215·0	½ = 107·5	100·0
Potassium	54·9	⅓ = 18·3	15·7
Copper	145·3	⅓ = 48·4	43·0
Zinc	71·2	⅓ = 23·4	22·6
Gallium	21·9	1 = 21·9	19·2
Palladium	125·0	⅓ = 41·7	36·3
Silver	74·7	⅓ = 24·9	24·7
Cadmium	30·7	⅓ = 10·2	13·1
Tin	27·6	½ = 13·8	14·5
Platinum	83·4	⅓ = 27·8	27·2
Gold	45·3	⅓ = 15·1	16·3
Mercury	7·5	⅓ = 2·5	2·8
Lead	17·7	⅓ = 5·9	5·4
Bismuth	14·4	1 = 14·4	12·4

Of the fifteen cases, the relation in eleven cases is one-third (in almost every case within the limits of the experimental errors); in two cases the fraction is apparently one-half, and in two cases unity. That for ten cases the ratio should be so uniform, with latent heats ranging from less than 3 to nearly 50, is an indication of some intimate connection between these physical constants of the elements.

Regarding the exceptional cases, it occurred to me that aluminium, tin and bismuth are known to act anomalously in many relations, as if their molecular structures were different from that of the other metals. (We have no data from which to discuss Gallium in these relations.) For instance, in lowering the freezing point of other metals, aluminium is known to act as if its molecular formula were double that of other metals in the molten state. In Pictet's observation of the connection between the melting point, coefficient of expansion and atomic volume of an element, bismuth and tin are among the chief exceptions.

[Pictet's rule is that the melting points of the elements (T, in absolute degrees) are, in many cases, inversely proportional to their coefficient of expansion by heat (a = linear expansion 0° to 100° C.) and to the relative distance of their atoms apart ($\sqrt[3]{V}$, where V is the atomic weight

divided by the specific gravity, or atomic volume) for which Pictet's relation is expressed by

$$T \cdot a \cdot \sqrt[3]{V} = 4{\cdot}5$$

or

$$T = \frac{4{\cdot}5}{a \cdot \sqrt[3]{V}}.$$

In fact, the products of these three quantities are not exactly equal, but vary between 4 and 5, the reason being, doubtless, that the average specific gravity and rate of expansion from — 273° to the melting point varies somewhat from the gravity at 20° and rate of expansion at 0° to 100° as used in his calculations.]

As already mentioned, bismuth and tin were Pictet's chief exceptions, and since they were anomalous in regard to their latent heat relations, I was led to compare these several relations among themselves, and to the following chain of reasoning: Since the atomic heats of the elements (specific heat into atomic weight) at 20° to 100° are, by Dulong and Petit's law, approximately equal to 6·4, then, assuming that the average specific heat from — 273° to the melting point does not vary much from the figure for 20° to 100°, the heat in atomic weight of a metal at its melting point is approximately 6·4 T; and, assuming the relation between the latent heat of fusion and the total heat in the metal at its melting point as $\frac{1}{3}$, the latent heat of fusion of an atomic weight of a metal becomes approximately 2·1 T.

But we can at once connect this expression with Pictet's rule, and write:

$$L = 2{\cdot}1\ T = \frac{4{\cdot}5 \times 2{\cdot}1}{a \cdot \sqrt[3]{V}} = \frac{9{\cdot}5}{a \cdot \sqrt[3]{V}},$$

where L is the latent heat of fusion of an atomic weight of the metal.

To test the validity of this expression (which, for reasons already explained, cannot claim exact accuracy), we will take Pictet's values for $a \cdot \sqrt[3]{V}$ (which are based on the best available data) and make the calculation for the metals whose latent heat of fusion and coefficient of expansion are both known.

	$L = \frac{9{\cdot}3}{a \cdot \sqrt[3]{V}}$	$\frac{L}{At.\ Wt.}$ = *for 1 kilo.*	*Latent heat experimentally obtained.*
Aluminium	1,900	70·4	100·0
Copper	3,006	46·2	43·0
Zinc	1,561	24·6	22·6
Palladium	3,832	36·1	36·3
Silver	2,541	23·5	24·7
Cadmium	1,253	11·1	13·1
Tin	1,712	13·7	14·5
Platinum	5,106	26·3	27·2
Gold	3,035	15·5	16·3
Mercury	654	3·3	2·8
Lead	1,284	6·2	5·4
Bismuth	2,777	13·4	12·4

Excepting aluminium, the coincidences are so close in the case of all the others that the calculated values in every case fall within the permissible limits of experimental errors, and it must be remembered that the above table contains *all* the metals for which the data are at present available. The non-metal sulphur expands so irregularly that no calculation can be made for it.

The closeness of the above coincidences may lead us to apply the formula to those other elements whose coefficients of expansion are known, but whose latent heat has not yet been determined, and thus to predict approximately the probable value of their latent heat of fusion.

	Calories.
Magnesium	58·
Pure iron	69·
Cobalt	68·
Nickel	68·
Selenium	13·
Ruthenium	46·
Rhodium	52·
Indium	8·
Antimony	16·
Tellurium	17·
Osmium	35·
Iridium	28·
Thallium	5·8

In the case of those other elements whose coefficients of expansion and specific heat are both unknown, the latent heats of fusion may be predicted, approximately, simply from the melting point, by using the relation $L = 2{\cdot}1\ T$.

The above comparisons, however, have shown that the dependence of the atomic latent heat of fusion on the absolute temperature of the melting point, or on the total heat in the metal at its melting point, is less exact than the dependence on the coefficient of expansion and atomic volume, and we should give the latter relationship preference in predicting unknown latent heats.

NOTES AND COMMENTS.*

CALCIUM CARBIDE AS A REDUCING AGENT.

By H. N. Warren.

The author says, in the *Chemical News*, that since the introduction of this remarkable substance, it is significant that scientific men have been content to allow the product to rank solely as a water decomposer, and thus regard the production of acetylene the only available product. Researches of a somewhat lengthy description, which have lately been carried out at the Liverpool Research Laboratory, involve the use of calcium carbide as a metallurgical reducing agent.

In the first instance an excess of litharge was heated to redness in contact with the carbide, in a clay crucible, the reaction being accompanied by vivid incandescence, resulting in the formation of metallic lead and calcium oxide, CaO. A further portion was now selected, in which the proportion of carbide exceeded that of the litharge; this was further subdivided into various smaller portions, each portion being exposed to various temperatures, resulting in a regulus of calcium and lead of varying percentage, together with the expulsion of CO_2.

The alloys thus formed are all more or less brittle, and to a certain extent sonorous when struck, their melting-point ranking below that of pure lead, and are slowly, but completely, decomposed in contact with aqueous vapor, the reaction being much less energetic than that afforded by alloys of lead with the alkaline metals. Stannic oxide, cupric oxide, and also ferric oxide, at corresponding higher temperatures, were readily reduced, yielding results of no practical value; in the case of the cupric alloys those samples containing under 1 per cent. of calcium being rendered cold-short and breaking under very small strain; while, on the other hand, iron containing calcium approaches in appearance that of ferro-manganese, being even more brittle, and very oxidizable in contact with water.

In a further operation, oxides of manganese, nickel, cobalt and even chromium, molybdenum and tungsten were readily reduced, yielding calcium alloys. Results of experiments comprising the reductive action of the carbide upon the earthy chlorides and their haloids will be shortly at hand. The already partial success of these reactions seems to point most conclusively

* From the Secretary's monthly reports.

toward a new and powerful reducing agent, which at the same time, considering the market value of the carbide in question, could not fail to replace both sodium and potassium.

PHOTOGRAPHY IN NATURAL COLORS.

According to a recent article in the London *Times*, a decided advance has been made in color photography, and one which appears to give results of great practical value. M. Villedieu Chassagne, of Paris, has lately submitted to the Society of Arts a process, the joint invention of himself and Dr. Adrien Michel Dansac, by which photographs can be produced showing the actual colors of the objects photographed. The process is a simple and inexpensive one. A negative is taken on a gelatine plate, which has been treated with a solution of certain salts; the nature of the solutions used is for the present kept secret. The negative is developed and fixed in the ordinary way, and, when finished, looks like any other negative. From it a positive is printed on sensitized paper or on a gelatine film (if a transparency is desired), plate or paper having previously been treated with the unknown solution. The positive looks exactly like an ordinary photographic print or transparency, and shows no trace of color. It is then washed over with three colored solutions, blue, green and red, and it takes up in succession the appropriate color in the appropriate parts, the combinations of the colors giving all varieties of tint. Thus, in a landscape, the trees take on various hues of green, the sky becomes blue, the flowers show their proper colors, the bricks and tiles of the houses are red, and so on. In a portrait the flesh tints come out well, and the different colors of the costume are accurately given. The general appearance of the picture is that of a colored photograph. Looked at from a distance, it would be taken for one. Inspected under a high magnifying power, it is seen that the colors follow the details in a manner hardly possible for hand-work. Further and independent investigation will no doubt throw some light on the principles involved. At present no explanation can be offered. The inventor himself does not profess to offer any, and, until further information is available, all speculation must be mere guesswork. It is to be said, however, that the subject certainly looks as if it would repay scientific examination and increase scientific knowledge.

SCIENTIFIC BREVITIES.

Gunz and Masson, continuing the experiments of the former, have shown that *aluminum will reduce CO or* CO_2. They find that, at a high temperature, in the presence of a little iodide or chloride of aluminum, aluminum is readily burned in a current of CO or CO_2. With CO the reaction is expressed by the following equation: $6Al + 3CO = Al_2O_3 + C_3Al_4$. On treating with boiling water, the aluminum carbide gives practically pure methane.——Trowbridge and Richards have proved that *argon*, at low pressures, *gives a blue fluorescence* under the action of the Herzian waves. The *Scientific American* reports the fact that *a self-toning collodion sensitized*

paper is prepared by coating the paper with a collodion emulsion mixed with the silver and the toning chemicals, such as chloride of gold. When a sheet of the paper is placed in the printing frame behind a negative the printing takes place in the usual way, but instead of being a red color it prints the same color as the ordinarily finished print does, the operation being continued until the print looks a trifle darker than is desired. It is then placed directly in a fixing bath composed of hyposulphite of soda and water for a few minutes, washed in changing water for half an hour, then dried and mounted. The prints are very satisfactory, equalling in brilliancy those made in the ordinary way, and are said to be fully as permanent.——Apropos to the rapidity with which Röntgen photographs can now be taken, London *Nature* refers to a series of pictures recently shown by Dr. John Macintyre at the Glasgow Philosophical Society. Dr. Macintyre passed through a kinematograph a film 35 feet long, having upon it radiographs of a limb of a frog, and he was thus able to show distinctly to a large audience the movements of the bones in the limb. To obtain the photographs the kinematograph was covered with lead in which there was the usual aperture. This aperture was covered with black paper. The tube was then put in the best condition, the mercury interrupter being used with a 10-inch spark coil. The movements of the limb of the frog were controlled by a mechanical arrangement.——As germane to the foregoing item, the fact appears to be well established that *prolonged exposure to the* direct action of the *Röntgen rays* is followed, at least in the case of some persons, by an injurious action upon the skin. A case was recently reported in the electrical journals (that of a boy of 10 years old) in which exposure of the cranium to the X-rays was followed, after the lapse of a few days, by the sudden falling out of the hair over the portion of the skull exposed. Reports of serious skin affections from the same cause have been reported. The latest account of this kind is given in the *Bulletin* of the Johns Hopkins Hospital. The writer, Mr. T. C. Gilchrist, after reviewing the several cases, finds that the X-rays are even more powerful than have been generally thought, and that the deleterious effects may, in some cases, be quite serious; the cutaneous manifestations are not, however, the most severe of the lesions, but they are surpassed in severity by those of the deeper tissues, and particularly of periosteum and bones. The discovery of this deeper and more profound effect calls for a new explanation to account for the cutaneous lesions. It seems probable that, according to the writer, these injurious effects may be due to the platinum particles piercing the bulb and then attacking the tissues. On clinical grounds, he states, there is considerable support for this, at first sight, improbable theory. If the lesion extends at all deeply it leads to the formation of ulcers, which are extremely intractable, and they may be due to irritating particles still present in the tissues. Mr. Gilchrist advises X-ray operators and experimenters, who develop any special idiosyncrasy, to abstain from their use if they find that the slightest deleterious results follow an exposure to them.——M. Henri Léon, in an essay on the *saltness of sea water*, gives in the Monthly Bulletin of the Biarritz Association the results of

analyses of water from different seas, which is thus summarized in the *Scientific American:* Taking 1,000 grammes of water, the result showed in the Atlantic 32·657 grammes of saline matter, in the Mediterranean 43·735, in the Black Sea 17·663, in the Sea of Azov 118·795, and in the Caspian 62·942. Among the saline matter chloride of sodium varied considerably. The sea was found to be less salt near the poles than at the equator, and was more salt at a distance from land and where it was of great depth than near the land and shallow. The Mediterranean is the exception, which is explained by the comparatively few rivers that freshen its waters. Salt lakes are frequently more salt than the ocean, as, for instance, the Dead Sea, which is ten times salter than the Atlantic.——From the same source we learn that some interesting investigations have been made on the *green color for which some Italian cheeses are so remarkable.* This color is not, as has sometimes been supposed, due to the action of bacteria, but is a consequence of the presence of copper in the cheese. To produce a good Parmesan cheese, the milk must reach a high degree of acidity, and, while waiting for this proper pitch of acidity to be acquired, the milk in some parts of Italy is kept standing in copper vessels. During this period of repose the milk takes up considerable quantities of copper; indeed, it is customary to estimate the degree of acidity attained by the milk by noting the gradual disappearance of the brightness of the highly polished, metallic surface. Dr. Mariani has examined twenty-five samples of green Parmesan cheese from various places, and has found that to about every 2 pounds of cheese there is present from 0·8 to 3·3 grains of copper. That this metal is solely responsible for the green color is evident from the fact that in the south of Italy cheese manufactured on the same principle, but in which the milk stands in tin-lined instead of copper vessels, does not acquire any green color.——Some recent observations made at the Howard College Observatory, on the spectrum of the star charted as *Zeta Puppis*, in addition to certain other peculiarities, have disclosed the existence on that body of *a new element* not found on the earth or on any other stars. The new substance resembles hydrogen, although it is quite distinct from it.——In the London *Electrician*, Leeds criticizes certain recent publications to the effect that a great revolution in *the art of producing aluminum* may be looked for within the next decade. His conclusions are adverse to this view. At present there is really only one method in use; it is highly probable that bauxite will remain the only available ore, as clay contains too little of the metal and too much silica, and cryolite is difficult to procure or reduce and is too impure. Several of the suggestions made are said to be visionary, and it is thought that the only alterations in the present method which are likely to take place will be in details effecting a decrease in price. If the present price could be reduced to one-half, aluminum would immediately become available as a conductor in the place of copper. W.

TECHNICAL BREVITIES.

The annual estimate made by Prof. W. C. Day, of the United States Geological Survey, regarding the *slate production of the United States for*

1896, shows the output of roofing slate last year to have amounted to 673,304 squares, valued at $2,263,748, while the production of slate for other purposes was valued at $482,457. Of this amount, Pennsylvania produced slate for roofing purposes of the value of $1,391,539, and for other purposes of the value of $334,770. The value of the total slate output of the United States showed an increase of $47,505, as compared with 1895. The increase, however, was entirely accounted for by the remarkably large export trade in roofing slates which developed in the latter half of 1896, owing to the strikes in the Welsh quarries. The home consumption fell considerably behind that of the previous year.——The Carborundum Company reports to the *Engineering and Mining Journal*, that its works have produced, during the year 1896, in round numbers, 1,191,000 pounds, or 595¼ tons, of crystalline carborundum. Consideration at the present is given to the production in crystalline form only, but another important industry, in which carbide of silicon promises to be a valuable adjunct, will naturally increase the usefulness of the material. Some mention has been made of the experiments showing that carborundum can be used, and will, in all probability, take the place of ferro-silicon in the manufacture of steel. Prof. Luehrmann, of Germany, recently wrote an article on this subject, indicating that in the use of carborundum there might be, in Germany alone, approximately, 2,500 tons consumed annually, provided its cost would not exceed 6 cents per pound. The amorphous form may be used for this purpose, and the Carborundum Company is prepared to furnish it at a price slightly under this figure.——By the consolidation of the two great iron manufacturing firms of Schneider and Canet, of Paris, the heads of the two foundries visited President Faure recently, and assured him that France now has *an iron manufacturing plant rivalling the Krupp establishment in Germany*.——The New *Panama Canal Company*, which is now said to be quietly but steadily working upon the construction of a lock-canal, was organized in Paris on October 1, 1894, just in time to save the concession from Colombia, which expired on October 31, 1894. Stockholders subscribed $4,000,000 toward the work, and from some of the promoters of the old company a further sum of $3,400,000 was forced. The report of the commission of Dutch, Belgian and French engineers, submitted in May, 1890, estimates that a lock-canal could be built for $180,000,000, including interest on the investment and 20 per cent. for contingencies. The United States of Colombia has granted a further concession, extending the time of completion to 1904. Under the present administration, it is claimed that the strictest economy is being practiced, and the latest devices for cheaply handling earth and rock are being introduced.——Dispatches from London, dated April 3d, say that the reports of the recent trial trips of the *roller steamer* at Rouen have been discouraging, the engines not proving powerful enough. Their power was nearly trebled, but the increased weight submerges the rollers so deep that they only turn ten times a minute instead of forty. The rollers throw up such quantities of water behind that each acts like a brake and reduces the anticipated 30 knots an hour to 6 or 7. Rubber scrapers are being experimented with to prevent the upheaval of the water.——*The Scientific American* states that a company engaged in the manufacture of *electric*

hansom cabs is now endeavoring, in New York, to compete with ordinary cabs drawn by horses. It was quite a time before the company could obtain the necessary permission to run its cabs for hire upon the streets, but the licenses having been obtained, the cabs are now a well-known sight in the upper part of New York, and occasionally they may be seen going as far down-town as Wall Street, winding in among the trucks and cable cars. This open competiton with horse-drawn vehicles may be regarded as one of the most satisfactory events in the motor-carriage world for a long time. W.

Franklin Institute.

[*Proceedings of the stated meeting, held Wednesday, April 21, 1897.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, April 21, 1897.

MR. JOHN BIRKINBINE, President, in the chair.

Present, 78 members and visitors.

Mr. Washington Jones was elected to the Board of Managers for the unexpired term of Mr. Theo. D. Rand, elected Vice-President.

Mr. Otto C. Wolf was elected to the Committee on Science and the Arts for the unexpired term of Prof. Arthur Beardsley, resigned.

The regular order of business was suspended, at the President's suggestion, and the meeting was devoted to the subject announced for discussion, viz.: "The Smoke Nuisance and its Regulation."

The discussion was introduced by a paper from Mr. A. E. Outerbridge, Jr., giving a brief historical sketch of the subject, and some data having especial reference to the smoke question as it affects Philadelphia.

The discussion was continued by brief addresses from the following members and others: Prof. R. H. Thurston, Ithaca, N. Y.; Mr. Wm. R. Roney, Baltimore, Md.; Mr. Wm. F. Durfee, West New Brighton, N. Y.; Mr. Edward Longstreth, Prof. Lewis M. Haupt, D. Ashworth & Son, Pittsburgh, Pa.; Col. Thos. P. Roberts, Engineer Monongahela Navigation Company, Pittsburgh, Pa.; Mr. Max Livingstone, Mr. Wm. M. Barr, Mr. James Christie, Mr. Arthur Kitson and Dr. Wm. H. Ford, President of the Philadelphia Board of Health.

The discussion was carried on until a late hour, and, on motion, its continuation was postponed until the stated meeting of May 19th.

[The discussion will be published in full in the *Journal.*]

Adjourned.

WM. H. WAHL, *Secretary.*

COMMITTEE ON SCIENCE AND THE ARTS.

[*Abstract of proceedings of the stated meeting held April 7, 1897.*]

MR. JAMES CHRISTIE in the chair.

Reports on the following subjects passed first reading:

Knife-Sharpener Attachment for Sewing Machines, Mary H. P. Cox.

Battery-Motor, A. A. Kent.

The Venturi Meter, Clemens Herschell, C. E., Providence, R. I. (Report of progress.)

Reports on the following subjects were adopted:

Black-Prints.—Process of Francis Leclere, Philadelphia.

ABSTRACT.—The products submitted by applicant are the results of a photo-chemical printing process. The term "black-prints" serves to distinguish these from the analogous products known as "blue-prints." The method is a copying process whereby a positive copy is obtained directly from a positive original, which latter must be transparent or translucent.

The method is briefly as follows: The paper sized, treated with the photogenic compound and dried, is exposed to the action of light under the design to be copied. The time required for exposure is short, as the paper is very sensitive. The exposed paper is then submitted successively to two liquids; the first, which acts as a mordant, and the second as a dye, which varies according to the color desired. The paper is floated on this liquid and absorbs the coloring pigment in the lines and spaces, which had previously been shielded from the action of light. The superfluous dye is washed out and the design appears on the white background of the paper in the desired color.

The report commends highly the quality of the results obtained, and gives the inventor credit for having demonstrated the utility of the process from the standpoint of economic production. The Scott Legacy Premium and Medal is recommended. [*Sub-Committee.*—Louis E. Levy, Samuel Sartain, Arthur Beardsley, John Haug.]

Piston Packing.—Edward F. Peacock, Philadelphia.

ABSTRACT.—The novel feature of this invention consists in the adaptation of a break-joint block of a piston-packing ring of the Ramsbottom type, for the purpose of preventing the escape of steam through the cut in the well-known Ramsbottom ring. The invention is held to be of doubtful utility. Covered by U. S. letters-patent, No. 407,370, July 23, 1889. [*Sub-Committee.*—J. M. Emanuel, H. F. Colvin, J. Logan Fitts, T. Carpenter Smith.]

Sand Track.—Claus Koepcke, Dresden, Saxony.

ABSTRACT.—The object of this inventon is to arrest the speed of a "wild train" quickly and safely without derailment or ditching, by means of an auxiliary track of standard gauge laid alongside the main track, and connected therewith by the usual switches and signals. This auxiliary track is laid at a slightly lower level than the main track, and is submerged in sand or other resistant material, confined by lateral stringers so as to constitute a trough into which the "wild train" is directed by the switch. The invention has been practically applied and tested in the railway yard in Dresden, and the results reported are highly satisfactory. The report recommends the invention to the attention of railway managers. Protected by U. S. letters-patent,

No. 494,718, April 4, 1893. [*Sub-Committee.*—Messrs. Lewis M. Haupt, Edgar Marburg, James Christie, H. F. Colvin, John L. Gill, Jr., S. M. Vauclain.]

Self-Cleansing Water Filter.—John W. Jarrett, Philadelphia.

ABSTRACT.—This device is intended for filtering water for manufacturing and domestic purposes. The filtering chamber, usually of cylindrical form, is provided at both ends with convex partitions of perforated sheet metal, called distributors, intended to check the force of the water entering the chamber. These distributors are held in place between flanges, by which the cylindrical shell and the heads are united; and between these flanges also, is placed, above and below, a sieve or strainer of wire gauze or other suitable substance. This arrangement of parts is held firmly united by means of exterior tie-rods. A lateral connection at the heads, above and below, is made to accommodate a pipe which has lateral inlet and outlet branches, by means of which, and a two-way cock, the direction of the entering and outflowing water-current may be directed either to the top or the bottom of the filtering chamber. By setting the lever controlling the two-way cock in one position, the course of the water is directed into the top of the filtering chamber, through the filtering material, of whatsoever character, out through the branch pipe at the bottom, at the upper part of which it is deflected by the discharge put through the lateral branch-pipe intended to deliver filtered water.

To cleanse the filter, it is simply necessary to reverse the position of the cock, when the course of the entering water is deflected into the bottom head, and passing through the filter head from below upwards, thoroughly agitates the same, carries the entangled foreign matter contained therein upwards, and discharges the impurities with the effluent water through the branch pipe at the top of the filter chamber. When the washing operation is completed, the position of the valve is again reversed, and the filtering operation is re-established.

The report admits the utility of the apparatus for its intended purpose, but does not recognize therein any element of novelty or originality of sufficient importance to warrant special commendation. Protected by U. S. letters-patent, No. 541,755, June 25, 1895. [*Sub-Committee.*—Samuel P. Sadtler, Frank P. Brown, Reuben Haines].

Flexible Metallic Tube.—T. R. Almond, Brooklyn, N. Y.

This tube consists of two helical coils, one inside the other, so disposed in relation to each other that the outside coil closes the space between the convolutions of the inside coil. The inside coil is originally wound perfectly close, and as the outside coil is wound over it, its convolutions are forced apart, the resulting tension effecting a close joint between the two coils. In the samples submitted for examination, the inside coil is of circular section, and the outer one of triangular section, the base of the triangle being on the outside and the apex on the inside of the coil.

Tubes which are not required to be air-tight (those, for instance, intended to support incandescent electric lamps) have the outside coil made of wire, the section of which is an equilateral triangle, while a more obtuse vertical angle is used for tubes intended to conduct fluids or gases, so as to obtain a greater normal pressure on the joint. These tubes are designed for use as adjustable supports for incandescent electric lights, for conducting oil or other

lubricating fluids to drills, boring tools, etc.; for conducting air to blow-pipes, etc. The tubes designed for conducting fluids were found to be perfectly tight against leakage and well adapted for their intended purpose. The "very conservative" claims of the inventor were found to be more than sustained. Protected by U. S. letters-patent, No. 424,044, March 25, 1890.

The John Scott Legacy Premium and Medal is recommended. [*Sub-Committee.*—Messrs. Hugo Bilgram, Robert D. Kinney, T. Carpenter Smith, Luther L. Cheney, J. Logan Fitts.

FOLLOWING is a list of applications received, and subjects referred by the Institute, for investigation by the Committee, since January 1, 1897:

No. 1950. Almond's Flexible Tubes, Application filed January 13.
" 1951. Koepcke's Sand-Track, Application filed January 21.
" 1952. Robertson's Nutritious Bread, Application filed January 29.
" 1953. Moissan's Investigations with the Electric Furnace, Investigation ordered March 6.
" 1954. Praul's Aërial Motor, Application filed February 26.
" 1955. Richards' Automatic Fluid-Pressure Friction Clutch, Application filed March 8.
" 1956. Williams' Typewriting Machine, Application filed March 8.
" 1957. Marsh's Metallic Corner Bead, Application filed March 9.
" 1958. Mueller's Process of and Apparatus for Manufacturing Mosaics, etc., Application filed March 10.
" 1959. Cox's Knife-Sharpener, Application filed March 12.
" 1960. Lewis' Improvement in Rotary Steam Engines, Application filed March 13.
" 1961. Corscaden's All-Wrought-Steel Belt Pulley, Application filed March 13.
" 1962. Groves' Gear Moulding Machine, Application filed March 15.
" 1963. Abatement of the Smoke Nuisance, Referred by Institute March 17.
" 1964. Dunn's Method for Measuring Intensities of Impulsive Forces, Referred by Institute March 17.
" 1965. Markley's Improvement in Wheels, Application filed March 20.
" 1966. Davis' Balanced Locomotive Driving-Wheel, Application filed March 23.
" 1967. Sanguinetti's Window Ventilator, Application filed April 7.
" 1968. Hollingshead's Automatic Disinfectant Ejector, Application filed April 8.
" 1969. Cazin's Percussion Wheel, Application filed April 19.
" 1970. Morrell's Duplication of the Cube, Application filed April 22.

W.

SECTIONS.

CHEMICAL SECTION.—The stated meeting Tuesday, April 20th, was devoted to a lecture by Dr. Henry Leffmann; subject, "The Chemistry of Food Adulteration." (To be published.)

ELECTRICAL SECTION.—The following card of proceedings is issued for the stated meeting of Tuesday, April 27th:

H. Lyman Sayen will exhibit and describe his "New Form of Crookes Tube, with Automatically Adjustable Vacuum; also Some New Forms of X-Ray Apparatus."

F. H. Lincoln, "Emergency Engineering," following the recent fire at the power station (Thirteenth and Mt. Vernon Streets) of the Union Traction Company.

C. J. Toerring, "The Enclosed Arc."

MINING AND METALLURGICAL SECTION.—The Board of Managers, at its stated meeting of Wednesday, April 14th, approved the formation of a Mining and Metallurgical Section, on the petition of the undermentioned members:

A. W. Allen,	Benj. S. Lyman,
Clarence S. Bement,	Henry G. Morris,
John Birkinbine,	H. S. Miner,
E. S. Balch,	Tinius Olsen,
Andrew A. Blair,	A. E. Outerbridge, Jr.,
Wm. Henry Bower,	Theo. D. Rand,
Wm. A. Bullock,	Wm. Tatham,
James Christie,	Wm. C. Day,
Thomas P. Conard,	John M. Hartman,
Walton Clark,	Wm. H. Greene,
James deBenneville,	C. J. Reed,
W. F. Durfee,	Jos. Richards,
Chas. B. Dudley,	Jos. W. Richards,
E. V. d'Invilliers,	Fred. A. Riehlé,
Theo. N. Ely,	Wm. Sellers,
Jacob B. Eckfeldt,	F. Schumann,
Francis Wyatt,	Frank Shuman,
Amos P. Brown,	Waldron Shapleigh,
Jos. Hartshorne,	H. T. Townsend,
T. M. Drown,	D. K. Tuttle,
W. S. Noyes,	Jos. Willcox,
Lee K. Frankel,	Wm. H. Wahl,
Henry Gawthrop,	W. R. Webster,
Fred. A. Genth, Jr.,	Jos. Westesson,
Fred. A. Gordon,	Asa W. Whitney,
F. L. Garrison,	Walter Wood,
Lyman B. Hall,	James M. Dodge,
Wm. C. Henderson,	Chas. James,
Morris P. Janney,	J. Pitman,
Walter M. James,	Thos. S. Parvin,
Harry F. Keller,	Wm. Burnham.

The first meeting for organization was held on Wednesday, April 28th, at 8 P.M. The following is the program:

Opening Address, Mr. John Birkinbine, President of the Institute.

"The Undeveloped Mineral Wealth of Newfoundland." Mr. A. E. Outerbridge, Jr.

"Compass Variation as Affected by Geological Structure in Bucks and Montgomery Counties, Pennsylvania." Mr. B. S. Lyman.